6.0 CONSERVATION STRATEGY OPTION 4 EVALUATION

Using the methods described in Section 2, this section presents an evaluation of Option 4. Option 4 is evaluated based on how it addresses each of the evaluation criteria and how it performs relative to the other Options and base conditions.

6.1 BIOLOGICAL CRITERIA

Option 4 includes construction and operation of a state-of-the-art positive barrier fish screen on the Sacramento River in the vicinity of Hood (Figure 1-5). Diversion of water for export would be exclusively from the Hood facility; no SWP or CVP exports would occur from the southern Delta. With the elimination of through-Delta water conveyance under Option 4 physical and hydrological habitat restoration and enhancement measures could be implemented at any location in the Delta (Figure 1-5). Results of the assessment of biological criteria and potential benefits to covered fish species under Option 4 are described in this section.

The evaluation of biological criteria for Option 4 is based on the hydrodynamic parameter values modeled for operational Scenarios A and B. The evaluation discussions presented below for each species and criterion, however, focus on Scenario A because:

- the type of effects of Scenario B on stressors and stressor impact mechanisms for each of the covered fish species are the same as described for Scenario A and a description of the performance of Scenario B would be repetitious;

- Scenario A would be more likely to achieve water supply objectives than Scenario B and, therefore, comparison of hydrodynamic outputs for scenario A across the Options puts each Option on an equivalent basis; and

- The magnitude of the effects of the Option on covered fish species differs between Scenarios A and B and, consequently, CALSIM II and DSM2 modeling results for Scenario B provided information useful in determining the range of flexibility within the Option to improve performance of the Option relative to achieving each of the biological criteria.

Though not described in the criteria evaluation text, the expected performance of Scenario B on each of the important stressors for each of the covered fish species relative to the performance of Scenario A is presented in summary tables at the beginning of each species evaluation section below.

Descriptions of the stressors and impact mechanisms addressed by the Options relative to each of the biological criteria and the tools used to measure changes in stressor effects are described in Section 3, "Conservation Strategy Option 1 Evaluation", and are not repeated in this section.

6.1.1 Delta Smelt

Based on the evaluation presented below of the expected performance of Option 4 for addressing important delta smelt stressors, Option 4 would be expected to have a high

beneficial effect on delta smelt production, distribution, and abundance relative to base conditions when operated to meet water supply objectives (Scenario A). If water supply exports are reduced (Scenario B), Option 4 would also be expected to provide a high beneficial effect on delta smelt production, distribution, and abundance relative to base conditions. Option 4 would be expected to provide higher benefits for delta smelt compared to the other Options.

Table 6-1 summarizes the expected effects of implementing Option 4 under Scenarios A and B on important delta smelt stressors relative to base conditions.

Table 6-1. Summary of Expected Effects of Option 4 on Highly and Moderately Important Delta Smelt Stressors

Stressors[1]	Applicable Criteria	Option Effects on Important Species Stressors Relative to Base Conditions	
		Scenario A	Scenario B
Highly Important Stressors			
Reduced food availability	1,3,4,5	High benefit	High benefit
Reduced rearing habitat	2,3	High benefit	High benefit
Reduced turbidity	1,2,3,5	Moderate benefit	Moderate benefit
Reduced spawning habitat	3	High benefit	High benefit
Reduced food quality	1,4,5	High benefit	High benefit
Moderately Important Stressors			
Predation	1,5	High benefit	High benefit
CVP/SWP entrainment	1	High benefit	High benefit
Exposure to toxics	1,2	Moderate adverse effect	Moderate adverse effect

Notes:

1. See Appendix C for descriptions of stressors, stressor impact mechanisms, and stressor effects.
2. It is recognized that the risk of entrainment at the SWP and CVP export facilities may be a high level stressor to delta smelt in some years and a very low level stressor to delta smelt in other years. For purposes of this analysis, the risk of delta smelt entrainment has been characterized, on average, as a moderate level stressor to the population.

6.1.1.1 Criterion #1. Relative degree to which the Option would reduce species mortality attributable to non-natural mortality sources, in order to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species.

Based on the following evaluation of Option 4 effects on applicable delta smelt stressors, Option 4 is expected to provide high benefits for delta smelt by reducing the effects of non-natural sources of mortality relative to base conditions.

Reduced Food Availability and Quality

The effects of Option 4 on delta smelt food availability and quality are evaluated under Criterion #4 below. As described in the Criterion #4 evaluation, Option 4 would be expected to provide a high beneficial effect on food availability and a high beneficial effect on food quality for the delta smelt relative to base conditions.

Reduced Turbidity

The effects of Option 4 on turbidity are evaluated under Criterion #2 below. As described in the Criterion #2 evaluation, Option 4 would be expected to provide moderate beneficial increase in turbidity conditions for delta smelt.

Predation

As described below under Criterion #2, Option 4 would be expected to moderately improve turbidity conditions relative to base conditions and, therefore, would be expected to reduce the vulnerability of delta smelt to predation. The proportion of the Delta (75%) within which physical habitat restoration could potentially be implemented is substantially greater than under the other Options (see Figure 1-5).

Based on the potential for improvement in turbidity conditions and the proportion of the Delta available for potential restoration, Option 4 would be expected to provide a high benefit by reducing the predation vulnerability of delta smelt relative to base conditions.

Entrainment by CVP/SWP Facilities

Under Option 4, all SWP and CVP diversions would occur from the Sacramento River near Hood. Risk for entrainment of delta smelt at the Hood intake facility would be minimal because the intake would be equipped with a positive barrier fish screen that would be expected to be highly effective in reducing the vulnerability of all but the early larval stages of delta smelt to entrainment. Furthermore, most delta smelt are believed to spawn downstream of the Hood intake location, thus reducing the proportion of the delta smelt population that is vulnerable to entrainment.[1] Removing the SWP and CVP exports from the south Delta under Option 4 would be expected to virtually eliminate the risk of delta smelt entrainment losses as a result of export operations. PTM modeling results also indicate that no entrainment of particles inserted downstream of Hood would be entrained at the intake facility. Based on this assessment, entrainment of delta smelt as a result of SWP and CVP export operations is expected to be nearly eliminated under Option 4 relative to base conditions.

[1] Results of fishery surveys conducted by CDFG and USFWS have shown that the majority of delta smelt inhabit the Sacramento River downstream of Walnut Grove and Georgiana Slough although a small number of delta smelt have been collected upstream of Hood in some years.

Exposure to Toxics

The effects of Option 4 on delta smelt exposure to toxics are evaluated under Criterion #2 below. As described in the Criterion #2 evaluation, Option 4 would be expected to have a moderate adverse increase in delta smelt exposure to toxics.

6.1.1.2 Criterion #2. Relative degree to which the Option would provide water quality and flow conditions necessary to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species.

Based on the following evaluation of Option 4 effects on applicable delta smelt stressors, Option 4 is expected to have a high beneficial effect on water quality and flow conditions that support delta smelt relative to base conditions.

Reduced Rearing Habitat

Results of hydrologic modeling indicate that the position of X_2 in April would be located 0.2 km upstream relative to base conditions and therefore would likely have no effect on the availability of rearing habitat. PTM modeling results indicate that a marginally to moderately higher number of particles are moved downstream past Chipps Island. Net downstream flows and Sacramento River flows at Rio Vista during March and April, which serve to transport larval smelt to downstream rearing habitats, however, would be reduced relative to base conditions (see Appendices F and H). As described below, Option 4 would be expected to improve turbidity conditions, thus improving the foraging efficiency of delta smelt and reducing their vulnerability to predation. Additionally, Option 4 would establish net westerly flows throughout the Delta that would improve transport and migration of delta smelt. The potential restoration of rearing habitats as described under Criterion #3 would also be expected to improve rearing habitat conditions. Consequently, overall Option 4 would be expected to have a high beneficial effect on rearing habitat accessibility and conditions relative to base conditions.

Reduced Turbidity

Option 4 is expected to moderately improve turbidity conditions for delta smelt relative to base conditions. Peak total Delta inflows from January through March are reduced from base conditions, indicating that turbidity inputs from Delta tributaries could be reduced from base conditions in those months. PTM modeling results for the central Delta indicate, however, that residence time would be substantially higher, thus creating the potential for increases in turbidity associated with primary and secondary production (see Appendices F and H). Restoration of aquatic shallow subtidal and intertidal habitats that could reduce the adverse effects of non-native aquatic pelagic and benthic organisms that filter sediment and organic materials from Delta waters could be located within approximately 75% of the Delta (Figure 1-5). Although peak Delta inflows could be reduced, improved turbidity conditions associated with increased hydraulic residence time and habitat restorations would be such that, overall, Option 4 would be expected to provide a moderate beneficial improvement in turbidity conditions for delta smelt relative to base conditions.

Exposure to Toxics

Dilution flows from the Sacramento River and other Delta tributaries are one way of reducing concentrations of toxics and their effect on delta smelt. Modeling results indicate that Option 4 would be expected to reduce dilution flows relative to base conditions, thus potentially increasing concentrations of toxics (see Appendices F and H). Furthermore, because the volume of water coming from the Sacramento River into the Delta would be reduced under Option 4, the contribution of the San Joaquin River water to water quality conditions within the Delta would be higher. Because San Joaquin River water is known to contain higher concentrations of toxics than Sacramento River water, Option 4 could increase the risk of exposing delta smelt to toxics. Although the effects of toxics on delta smelt are uncertain, Option 4 has the potential for having a moderate adverse effect on delta smelt by increasing the exposure of delta smelt to higher concentrations of toxics. Under Option 4, however, there are potential opportunities to restore intertidal wetlands in the south Delta that could filter toxics from the San Joaquin River before it discharges into the central Delta, which would reduce the likelihood for toxic effects on delta smelt.

6.1.1.3 Criterion #3. Relative degree to which the Option would increase habitat quality, quantity, accessibility, and diversity in order to enhance and sustain production (reproduction, growth, survival), abundance, and distribution; and to improve the resiliency of each of the covered species' populations to environmental change and variable hydrology.

Based on the following evaluation of Option 4 effects on applicable delta smelt stressors, Option 4 is expected to provide high benefits relative to habitat conditions for the delta smelt.

Within the planning area, delta smelt habitat conditions are governed by hydrodynamic conditions and the extent and quality of habitat within the planning area. Under Option 4, these conditions relative to base conditions would be affected by the conveyance configuration of Option 4 and restoration of physical habitat that could potentially be sited within Suisun Bay and Marsh and within 75% of the planning area, which encompasses the known and potential range of delta smelt within the Delta.

Reduced Food Availability

The effects of Option 4 on delta smelt food availability are evaluated under Criterion #4 below. As described in the Criterion #4 evaluation, Option 4 would be expected to provide a high beneficial effect on food supply for the delta smelt relative to base conditions.

Reduced Rearing Habitat

Under Option 4, in addition to the flow benefits for rearing habitat conditions described above under Criterion #2, habitat could be restored within Suisun Bay and Marsh and approximately 75% of the Delta to provide high quality shallow aquatic subtidal and intertidal habitat (Figure 1-4), which encompasses a larger proportion of the delta smelt rearing range than the area that potentially would be available and suitable for restoration under the other Options. Consequently, relative to base conditions and the other Options, Option 4 would be expected to provide a high benefit for delta smelt rearing habitat.

Reduced Turbidity

The effects of Option 4 on turbidity are evaluated under Criterion #2 above. As described in the Criterion #2 evaluation, Option 4 would be expected to provide moderate beneficial increases in turbidity conditions.

Reduced Spawning Habitat

The primary impact mechanism believed to affect spawning habitat is the reclamation and channelization of historical shallow subtidal and intertidal wetlands that has presumably reduced the amount of habitat available for spawning by delta smelt. Under Option 4, physical aquatic and subtidal and intertidal habitats could potentially be restored at sites located over 75% of the Delta (Figure 1-5), which encompasses a substantially larger proportion of the likely spawning range of delta smelt than restoration that could be implemented under the other Options. Consequently, to the extent that functioning delta smelt spawning habitat can be successfully restored based on current understanding of its habitat requirements, restoration under Option 4 would be expected to provide a high benefit (see Appendix H) relative to base conditions and other Options.

6.1.1.4 Criterion #4. Relative degree to which the Option would increase food quality, quantity, and accessibility (e.g., phytoplankton, zooplankton, macro-invertebrates, forage fish) to enhance production (reproduction, growth, survival) and abundance for each of the covered fish species.

Overall, Option 4 would be expected to provide high benefits for improving food availability and quality for delta smelt.

Reduced Food Availability

The potential opportunities for habitat restoration that could be implemented under Option 4 would all be located within the geographic range of delta smelt and could create conditions that disfavor non-native species that indirectly or directly affect food abundance (e.g., overbite clam (*Corbula*), threadfin shad), thereby improving food availability for delta smelt relative to base conditions (Figure 1-5). Because habitat restorations could potentially be sited within a larger proportion of the delta smelt's range within the Delta (75% of the Delta would be potentially available and suitable restoring delta smelt habitat), habitat restoration under Option 4 is expected to improve food availability relative to the other Options and base conditions.

The magnitude of peak flows from January through March, the period during which Delta inflows have been greatest historically, gives an indication of the potential for floodplain inundation relative to base conditions. Modeled peak Delta inflows under Option 4 during January through March are substantially lower relative to base conditions (see Appendices F and H). Therefore, relative to base conditions, Option 4 would be expected to have a low adverse effect on the transport of organic material and nutrients from floodplains into the Delta. An increase in the extent of shallow water tidal and subtidal habitat in the Delta under Option 4 would provide additional opportunities to inundate areas having high production and contribute to nutrient and organic material transport through the Delta. The opportunities for

in-Delta inundated aquatic habitat are greater under Option 4 than the other three Options evaluated.

Based on PTM modeling results for exported particles, the removal of food organisms, nutrients, and organics by diversions would be substantially lower relative to base conditions. Under Option 4, all SWP and CVP diversions would be made directly from the Sacramento River, thereby substantially reducing the export of nutrients, organic material, phytoplankton, and zooplankton from the Delta. PTM modeling results for particles released into the central Delta, an indictor of hydrologic residence time, indicated that hydraulic residence time within the central Delta would be higher relative to base conditions. Increased residence time is generally beneficial for delta smelt food supply, however, high residence time could have adverse effects on central Delta biota if it is too great. Dissolved oxygen levels can be depressed by high biological oxygen demand resulting from high densities of phytoplankton and reduced hydraulic flushing. Particle tracking models were run for a period of 40 days and, even after this duration, 90% of the particles injected at Middle River remained in the central Delta under the 50% exceedance hydrology. However, in most other scenarios and insertion locations, high residence time does not appear to be a concern under Option 4. Based on these results, Option 4 would be expected to provide a moderate benefit for delta smelt associated with a reduction in exports of nutrients and organic material that support delta smelt food supplies.

Historically, much of the energy in the Delta ecosystem was derived from wetland tules (The Bay Institute 1998). Therefore, combined with the wetland restoration potential in the Delta under Option 4, the increases in residence time within the Delta, and the reduction in the export of nutrients, organics, and zooplankton from the Delta, Option 4 is expected to provide a high beneficial increase in the availability of food for delta smelt.

Reduced Food Quality

Restoration of shallow water tidal and subtidal habitats under Option 4 could improve nutrient production and production of suitable zooplankton species (e.g., native calanoid copepods) as forage for delta smelt. Under Option 4, physical aquatic subtidal and intertidal habitats could be restored at sites located over 75% of the Delta (Figure 1-5), which encompasses a substantially larger proportion of the likely spawning range of delta smelt than restoration that could be implemented under the other Options. Consequently, relative to the other Options, Option 4 would be expected to provide a potentially high benefit for food quality (see Appendix H).

6.1.1.5 Criterion #5. Relative degree to which the Option would reduce the abundance of non-native competitors and predators to increase native species production (reproduction, growth, survival), abundance and distribution for each of the covered fish species.

Option 4 could reduce the effects of non-native competitors and predators on delta smelt primarily through restoration of intertidal and subtidal aquatic habitats at potential locations throughout the Delta. For reasons described in above, Option 4 would be expected to provide a high beneficial effect by reducing the adverse effects of populations of non-native food competitors relative to base conditions. For reasons described under Criteria #1 and #2, Option 4 could provide a moderate beneficial effect by reducing the risk of delta smelt predation relative to base conditions. Additionally, because the intake under Option 4 would be located

on the Sacramento River upstream near Hood, Delta hydrodynamics would largely revert to a more natural east to west flow pattern through the Delta. Option 4 presents opportunities to adaptively manage Delta hydrodynamics to create hydrodynamic conditions that would be expected to favor the delta smelt and disfavor predators and competitors to improve conditions for the delta smelt. Although the ability to control non-native species by varying hydrodynamic conditions in the Delta is uncertain, Option 4 provides a greater opportunity for doing so than Options 1 and 2.

6.1.1.6 Criterion #6. Relative degree to which the Option improves ecosystem processes in the BDCP planning area to support aquatic and associated habitats.

Based on the proportion of the planning area suitable for potential restoration under Option 4 relative to the other Options and modeling results for hydraulic residence time (see Appendix H), Option 4 would be expected to provide a low beneficial improvement in ecosystem function relative to base conditions.

Under the range of operations and the potential opportunities to restore/enhance high quality aquatic habitat within the Delta habitat the effectiveness of Option 4 in improving ecosystem processes is considered to be high. These changes would be expected to improve ecosystem processes within the central and western regions of the Delta when compared to base conditions. In addition, the ability to divert water directly from the Sacramento River at Hood while eliminating the export operations within the south Delta would be expected to substantially improve the hydrodynamics of the Delta and improve the quality of habitat available for delta smelt. Under these operating conditions Option 4 offers the opportunity to improve the processes affecting habitat conditions within the Delta (e.g., providing net westerly flows, reducing or eliminating reverse flow conditions, etc.). These potential changes to the estuarine processes within the Delta are expected to benefit delta smelt and other species. It is uncertain, however, if increasing the proportion of lower quality San Joaquin River water present in the Delta (a function of reducing Sacramento River inflow and eliminating export of San Joaquin River water from the Delta) into the central and western Delta would impair ecosystem processes.

6.1.1.7 Criterion #7. Relative degree to which the Option can be implemented within a timeframe to meet the near-term needs of each covered fish species (post BDCP authorization).

In the near-term, until construction of Option 4 conveyance features and facilities is completed, this Option would use the existing conveyance facilities to meet water supply objectives. As for Option 1, implementation of physical habitat restoration under Option 4 in the north and west Delta can be initiated immediately following authorization of the BDCP and thus could be implemented in a manner that would meet the near term needs of delta smelt.

6.1.2 Longfin Smelt

Based on the evaluation presented below of the expected performance of Option 4 for addressing important longfin smelt stressors, Option 4 would be expected to have a high beneficial effect on longfin smelt production, distribution, and abundance relative to base conditions when operated to meet water supply objectives (Scenario A). If water supply

exports are reduced (Scenario B), Option 4 would also be expected to provide a high beneficial effect on longfin smelt production, distribution, and abundance relative to base conditions. Option 4 would be expected to provide higher benefits for longfin smelt compared to the other Options.

Stressors that affect longfin smelt are presented in Figure 2-2 and are described in Appendix C. The effect of these stressors on the longfin smelt population vary among years in response to environmental conditions (e.g., seasonal hydrology) and may also interact with each other in additive or synergistic ways. The effects of these stressors include both the incremental contribution of a stressor to the population as well as the cumulative effects of multiple stressors over time. The assessment evaluates the degree to which Option 4 would be expected to address these stressors.

Table 6-2 summarizes the expected effects of implementing Option 4 under Scenarios A and B on important longfin smelt stressors relative to base conditions.

Table 6-2. Summary of Expected Effects of Option 1 on Highly and Moderately Important Longfin Smelt Stressors

Stressors[1]	Applicable Criteria	Option Effects on Important Species Stressors Relative to Base Conditions	
		Scenario A	Scenario B
Highly Important Stressors			
Reduced access to spawning habitat	2	No net effect	No net effect
Reduced access to rearing habitat	2	Very low benefit	Low benefit
Reduced food	1,4,5	High benefit	High benefit
Predation	1,5	High benefit	High benefit
Reduced turbidity	1,2, 3,5	Moderate benefit	Moderate benefit
Reduced spawning habitat	3	High benefit	High benefit
Reduced food quality	1,4,5	High benefit	High benefit
Moderately Important Stressors			
CVP/SWP entrainment[2]	1	High benefit	High benefit
Reduced rearing habitat	2	Low benefit	Low benefit
Exposure to toxics	2	Moderate adverse effect	Moderate adverse effect

Notes:

1. See Appendix C for descriptions of stressors, stressor impact mechanisms, and stressor effects.
2. Although it is recognized that the risk of entrainment at the SWP and CVP export facilities may, in some years, be a high level stressor to longfin smelt, and in some years represents a very low level stressor to longfin smelt, for purposes of the analysis the risk of longfin smelt entrainment under each of the Options has been characterized, on average, as a moderate level stressor to the population.

6.1.2.1 Criterion #1. Relative degree to which the Option would reduce species mortality attributable to non-natural mortality sources, in order to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species.

Based on the following evaluation of Option 4 effects on applicable longfin smelt stressors, Option 4 is expected to provide high benefits for longfin smelt by reducing the effects of non-natural sources of mortality relative to base conditions.

Reduced Food Availability and Quality

Reduced food availability and quality can result in non-natural levels of mortality. The effects of Option 4 on longfin smelt food availability and quality are evaluated under Criterion #4 below. As described in the Criterion #4 evaluation, Option 4 would be expected to provide a high beneficial effect on food availability and quality for longfin smelt relative to base conditions.

Reduced Turbidity

Reduced turbidity may increase the vulnerability of longfin smelt to predation and reduce foraging efficiency. The effects of Option 4 on turbidity are evaluated under Criterion #2 below. As described in the Criterion #2 evaluation, Option 4 would be expected to provide moderate beneficial increases in turbidity conditions relative to base conditions.

Predation

As described below under Criterion #2, Option 4 would be expected to moderately improve turbidity conditions relative to base conditions and, therefore, would be expected to reduce the vulnerability of longfin smelt to predation. The proportion of the Delta (75%) within which physical habitat restoration could potentially be implemented is substantially greater than under the other Options (see Figure 1-5). Based on the potential for improvement in turbidity conditions and the proportion of the Delta available for restoration, Option 4 would be expected to provide a high benefit by reducing the predation vulnerability of longfin smelt relative to base conditions.

Entrainment by CVP/SWP Facilities

Under Option 4, all SWP and CVP diversions would occur from the Sacramento River near Hood. Risk for entrainment of longfin smelt at the Hood intake facility would be minimal because the intake would be equipped with a positive barrier fish screen that would be expected to be highly effective in reducing the vulnerability of all but the early larval stages of longfin smelt to entrainment. Furthermore, most longfin smelt are believed to spawn downstream of the Hood intake location, thus reducing the proportion of the longfin smelt population that is vulnerable to entrainment.[2] Removing the SWP and CVP exports from the south Delta under Option 4 would be expected to virtually eliminate the risk of longfin smelt

[2] Results of fishery surveys conducted by CDFG and USFWS have shown that the majority of longfin smelt inhabit the Sacramento River downstream of Walnut Grove and Georgiana Slough although a small number of longfin smelt have been collected upstream of Hood in some years

entrainment losses as a result of export operations. PTM modeling results also indicated that no particles inserted downstream of Hood would be entrained at the intake facility. Based on this assessment, entrainment of longfin smelt as a result of SWP or CVP export operations is expected to be nearly eliminated under Option 4 relative to base conditions.

Exposure to Toxics

The effects of Option 4 on longfin smelt exposure to toxics are evaluated under Criterion #2 below. As described in the Criterion #2 evaluation, Option 4 would be expected to have a moderate adverse increase in longfin smelt exposure to toxics.

6.1.2.2 Criterion #2. Relative degree to which the Option would provide water quality and flow conditions necessary to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species.

Based on the following evaluation of Option 4 effects on applicable longfin smelt stressors, Option 4 is expected to provide very low benefits for water quality and flow conditions that support longfin smelt relative to base conditions.

Reduced Access to Spawning Habitat

Access of adult longfin smelt to spawning habitat is thought to be a function of river flows and availability and quality of habitat. Under Option 4 flows within the Sacramento River during the late winter and early spring longfin smelt spawning period are expected to be reduced when compared to base conditions. Lower winter and early spring flows may reduce upstream attraction and movement of adult longfin smelt and would also be expected to contribute to reduce downstream transport of larval and early juvenile smelt. Flows on the San Joaquin River have been assumed, for purposes of these analyses, to be similar under base conditions and Option 4. Option 4 includes the opportunity to potentially enhance intertidal and subtidal habitat at a wide range of locations throughout Delta that would be expected to benefit longfin smelt when compared to base conditions.

Reduced Access to Rearing Habitat

PTM modeling results indicate that a marginally to moderately higher number of particles would be moved past Chipps Island or into Suisun Marsh. Net downstream flows and Sacramento River flows at Rio Vista during March and April, which serve to transport larval smelt to downstream rearing habitats, however, would be reduced relative to base conditions (see Appendices F and H) which potentially could result in a marginal reduction in larval longfin smelt survival. Consequently, Option 4 would be expected to have a very low beneficial effect on accessibility of rearing habitat.

Reduced Turbidity

Option 4 is expected to moderately improve turbidity conditions for longfin smelt relative to base conditions. Peak total Delta inflows from January through March are reduced from base conditions, indicating that turbidity inputs from Delta tributaries could be reduced from base conditions in those months. PTM modeling results for the central Delta indicate, however, that

residence time would be substantially higher, thus creating the potential for increases in turbidity associated with primary and secondary production (see Appendices F and H). Restoration of aquatic subtidal and intertidal habitats that could reduce the abundance and/or impacts of non-native aquatic and benthic organisms that filter sediment and organic materials from Delta waters could potentially be located within approximately 75% of Delta (Figure 1-5). Although peak Delta inflows could be reduced, improved turbidity conditions associated with increased hydraulic residence time and habitat restorations would be such that, overall, Option 4 would be expected to provide a moderate beneficial improvement in turbidity conditions for longfin smelt relative to base conditions.

Exposure to Toxics

Dilution flows from the Sacramento River and other Delta tributaries are one way of reducing concentrations of toxics and their effect on longfin smelt. Modeling results indicate that Option 4 would be expected to reduce dilution flows relative to base conditions, thus potentially increasing concentrations of toxics (see Appendices F and H). Furthermore, because the volume of water coming from the Sacramento River into the Delta would be reduced under Option 4, the contribution of the San Joaquin River water to water quality conditions within the Delta will be higher. Because San Joaquin River water is known to contain higher concentrations of toxics than Sacramento River water, Option 4 could increase the risk of exposing longfin smelt to toxics. Although the effects of toxics on longfin smelt are uncertain, Option 4 has the potential for having a moderate adverse effect by increasing the exposure of longfin smelt to higher concentrations of toxics. Under Option 4, however, there are opportunities to restore intertidal and subtidal wetlands and seasonally inundated floodplains in the south Delta that could filter toxics from the San Joaquin River before it discharges into the central Delta, which would reduce the likelihood for toxic effects on longfin smelt.

Reduced Rearing Habitat

Results of hydrologic modeling indicate that the position of X_2 in April would be located 0.2 km upstream relative to base conditions and, therefore would likely have no effect on the availability of rearing habitat. As described below, Option 4 would be expected to improve turbidity conditions, thus improving the foraging efficiency of longfin smelt and reducing their vulnerability to predation. Consequently, overall Option 4 would be expected to have a low beneficial effect on rearing habitat conditions relative to base conditions.

6.1.2.3 Criterion #3. Relative degree to which the Option would increase habitat quality, quantity, accessibility, and diversity in order to enhance and sustain production (reproduction, growth, survival), abundance, and distribution; and to improve the resiliency of each of the covered species' populations to environmental change and variable hydrology.

Based on the following evaluation of Option 4 effects on applicable longfin smelt stressors, Option 4 is expected to provide moderate benefits relative to habitat conditions for the longfin smelt.

Within the planning area, longfin smelt habitat conditions are governed by hydrodynamic conditions and the extent and quality of suitable habitat. Relative to base conditions, these

conditions under Option 4 would be affected by the conveyance configuration and potential restoration of physical habitat that could be located over a wide range of locations representing approximately 75% of the planning area.

Reduced Access to Spawning and Rearing Habitats

The effects of Option 4 on the accessibility of spawning and rearing habitats are evaluated under Criterion #2 above. As described in the Criterion #2 evaluation, Option 4 would be expected to affect longfin smelt access to spawning habitat and would be expected to reduce seasonal flows within the lower reaches of the Sacramento River that serve to transport larval and early longfin smelt to downstream juvenile rearing habitat.

Reduced Food Availability and Quality

Reduced food availability and quality can result in non-natural levels of mortality. The effects of Option 4 on longfin smelt food availability and quality are evaluated under Criterion #4 below. As described in the Criterion #4 evaluation, Option 4 would be expected to provide a high beneficial effect on food availability and quality for longfin smelt relative to base conditions.

Reduced Turbidity

Habitat conditions that support non-native filter feeders and aquatic plants can reduce turbidity. The effects on turbidity associated with these impact mechanisms are evaluated under Criterion #2 above. As described in the Criterion #2 evaluation, restoring habitat under Option 4 would be expected to have a moderate beneficial effect on turbidity conditions for longfin smelt relative to base conditions.

Reduced Spawning Habitat

The primary impact mechanism believed to affect spawning habitat is the reclamation and channelization of historical intertidal and subtidal wetlands that has presumably reduced the amount of habitat available for spawning by longfin smelt. Under Option 4, physical aquatic subtidal and intertidal habitats could potentially be restored at sites located over 75% of the Delta (Figure 1-5), which encompasses a substantially larger proportion of the likely spawning range of longfin smelt than restoration that could be implemented under the other Options. Consequently, relative to the other Options and to the extent that functioning longfin smelt spawning habitat can be successfully restored based on current understanding of its habitat requirements, restoration under Option 4 would be expected to provide a high benefit (see Appendix H) relative to base conditions.

Reduced Rearing Habitat

The effects on rearing habitat associated with Option 4 are evaluated under Criterion #2 above. Option 4 is expected to have a low beneficial effect on rearing habitat conditions relative to base conditions.

6.1.2.4 Criterion #4. Relative degree to which the Option would increase food quality, quantity, and accessibility (e.g., phytoplankton, zooplankton, macro-invertebrates, forage fish) to enhance production (reproduction, growth, survival) and abundance for each of the covered fish species.

Overall, Option 4 would be expected to provide high benefits for improving food availability and quality for longfin smelt.

Reduced Food Availability

The habitat restoration that would be implemented under Option 4 would all be located within the geographic range of longfin smelt and could create conditions that disfavor non-native species that indirectly or directly affect food abundance (e.g., overbite clam (*Corbula*), threadfin shad), thereby improving food availability for longfin smelt relative to base conditions (Figure 1-5). Because habitat restorations could potentially be sited within a larger proportion of the longfin smelt's range within the Delta (75% of the Delta could be available for restoration/enhancement), habitat restoration under Option 4 is expected to improve food availability relative to the other Options and base conditions.

The magnitude of peak flows from January through March, the period during which inflows have been greatest into the Delta historically, gives an indication of the potential for floodplain inundation relative to base conditions. Modeled peak Delta inflows under Option 4 during January through March are substantially lower relative to base conditions (see Appendices F and H). Therefore, relative to base conditions, Option 4 would be expected to have a low adverse effect on the mobilization and transport of organic material and nutrients from floodplains into the Delta. The potential to increase the extent of shallow water intertidal and subtidal habitat within the Delta under Option 4 would provide additional opportunities to inundate areas having high production and contribute to nutrient and organic material transport through the Delta. The opportunities for in-Delta inundated aquatic habitat are greater under Option 4 than the other three options evaluated.

Based on PTM modeling results for exported particles, the removal of food organisms, nutrients, and organics by diversions would be substantially lower relative to base conditions. Under Option 4, all SWP and CVP diversions would be made directly from the Sacramento River, thereby substantially reducing the export of nutrients, organic material, phytoplankton, and zooplankton from the Delta. PTM modeling results for particles released into the central Delta, an indictor of hydrologic residence time, indicated that hydraulic residence time within the central Delta was much higher relative to base conditions. Increased residence time is generally beneficial for longfin smelt food supply, however, high residence time could have adverse effects on central Delta biota if it is too great. Dissolved oxygen levels can be depressed by high biological oxygen demand resulting from high densities of phytoplankton and reduced hydrologic flushing. Particle tracking models were run for a period of 40 days and, even after this duration, 90% of the particles injected at Middle River remained in the central Delta under the 50% exceedance hydrology. However, in most other scenarios and insertion locations, high residence time does not appear to be a concern under Option 4. Based on these results, Option 4 would be expected to provide a moderate benefit for longfin smelt associated with a reduction in exports of nutrients and organic material that support longfin smelt food supplies.

It has been hypothesized that exposure of phytoplankton and zooplankton to toxics (e.g., pesticides, herbicides) that enter the Delta from point and non-point sources may contribute to ongoing low abundance of longfin smelt zooplankton prey species (Weston et al. 2004, Luoma 2007). Though this relationship is uncertain, Option 4 could potentially increase the exposure of primary and secondary producers to elevated concentrations of these toxics because dilution flows would be lower than base conditions.

Historically, much of the energy in the Delta ecosystem was derived from wetland tules (The Bay Institute 1998). Therefore, combined with the wetland restoration potential in the Delta under Option 4, the increases in residence time within the Delta, and the reduction in the export of nutrients, organics, and zooplankton from the Delta, Option 4 is expected to provide a high beneficial increase in the availability of food for longfin smelt.

Reduced Food Quality

Restoration of shallow water intertidal and subtidal habitats under Option 4 could improve nutrient production and production of suitable zooplankton species (e.g., native calanoid copepods) as forage for longfin smelt. Under Option 4, physical aquatic subtidal and intertidal habitats could potentially be restored at sites located over 75% of the Delta (Figure 1-5), which encompasses a substantially larger proportion of the range of rearing and foraging juvenile and adult longfin smelt than restoration that could be implemented under the other Options. Consequently, relative to the other Options, Option 4 would be expected to provide a potentially high benefit for food quality (see Appendix H).

6.1.2.5 Criterion #5. Relative degree to which the Option would reduce the abundance of non-native competitors and predators to increase native species production (reproduction, growth, survival), abundance and distribution for each of the covered fish species.

Option 4 could reduce the effects of non-native competitors and predators on longfin smelt primarily through restoration of intertidal and subtidal aquatic habitats located throughout the Delta. For reasons described above, Option 4 would be expected to provide a moderate beneficial effect by reducing populations and/or the impacts of non-native food competitors relative to base conditions. For reasons described under Criteria #1 and #2, Option 4 could provide a moderate beneficial effect by reducing the risk of longfin smelt predation relative to base conditions. Additionally, because the intake under Option 4 would be located upstream near Hood, Delta hydrodynamics would largely revert to a more natural east to west flow pattern through the Delta and presents opportunities to restore and adaptively manage hydrodynamic conditions that favor the longfin smelt and disfavor predators and competitors to improve conditions for the longfin smelt. Although the ability to control non-native species by varying hydrodynamic conditions in the Delta is uncertain, Option 4 provides a greater opportunity for doing so than Options 1, 2, or 3.

6.1.2.6 Criterion #6. Relative degree to which the Option improves ecosystem processes in the BDCP planning area to support aquatic and associated habitats.

Based on the proportion of the planning area suitable for potential restoration under Option 4 relative to the other Options and modeling results for hydraulic residence time (see Appendix H), Option 4 would be expected to provide a high beneficial improvement in ecosystem

function relative to base conditions. Operations under Option 4 would return Delta hydrodynamic conditions to a more normal east-west direction and would avoid reverse flow conditions. The changes in hydrodynamic conditions under Option 4 would directly contribute to improving estuarine processes.

Under the range of operations and the potential opportunities to restore/enhance high quality aquatic habitat within the Delta habitat the effectiveness of Option 4 in improving ecosystem processes is considered to be high. These changes would be expected to improve ecosystem processes throughout the Delta when compared to base conditions. In addition, the ability to divert water directly from the Sacramento River at Hood while eliminating the export operations within the south Delta would be expected to substantially improve the hydrodynamics of the Delta and improve the quality of habitat available for longfin smelt. Under these operating conditions Option 4 offers the opportunity to improve the processes affecting habitat conditions within the Delta (e.g., providing net westerly flows, reducing or eliminating reverse flow conditions, etc.). These potential changes to the estuarine processes within the Delta are expected to benefit longfin smelt and other species. It is uncertain, however, if increasing the proportion of low quality San Joaquin River water present in the Delta (a function of reducing Sacramento River inflow and eliminating export of San Joaquin River water from the Delta) into the central Delta would impair ecosystem processes.

6.1.2.7 Criterion #7. Relative degree to which the Option can be implemented within a timeframe to meet the near-term needs of each covered fish species (post BDCP authorization).

In the near-term, until construction of Option 4 conveyance features and facilities is completed, Option would use the existing conveyance facilities to meet water supply objectives. As for Option 1, implementation of physical habitat restoration under Option 4 in the north and west Delta can be initiated immediately following authorization of the BDCP and thus could be implemented in a manner that would meet the near term needs of longfin smelt.

6.1.3 Sacramento River Salmonids

Overall, Option 4 is expected to provide high benefit to Sacramento River Chinook salmon and steelhead compared to base conditions. Operations under Option 4, including diversion from the Sacramento River using a state-of-the-art positive barrier fish screen, would substantially reduce or potentially eliminate adverse impacts related to entrainment of juvenile salmonids from the Sacramento River. The potential opportunities for habitat restoration and enhancement of both physical habitat and natural hydrology under Option 4 would be the greatest among the Options.

Table 6-3 and 6-4 summarizes the expected effects of implementing Option 4 under Scenarios A and B on important delta smelt stressors relative to base conditions.

Table 6-3. Summary of Expected Effects of Option 4 on Highly and Moderately Important Sacramento River Chinook Salmon Stressors

Applicable Criteria	Stressor[1]	Option Effects on Important Species Stressors Relative to Base Conditions	
		Scenario A	Scenario B
Highly Important Stressors			
2,3	Reduced staging and spawning habitat	Very low benefit	Very low benefit
2,3	Reduce rearing and outmigration habitat	Moderate benefit	Moderate benefit
1	Predation by non-natives	High benefit	High benefit
Moderately Important Stressors			
1	Harvest	No net effect	No net effect
1	Reduced genetic diversity/integrity	No net effect	No net effect
1,	SWP/CVP entrainment	High benefit	High benefit
1,2	Exposure to toxics	Moderate adverse effect	Moderate adverse effect
2,3	Increased water temperature	No net effect	No net change

Notes:
1. See Appendix C for descriptions of stressors, stressor impact mechanisms, and stressor effects.

Table 6-4. Summary of Expected Effects of Option 4 on Highly and Moderately Important Sacramento River Steelhead Stressors

Applicable Criteria	Stressor[1]	Option Effects on Important Species Stressors Relative to Base Conditions	
		Scenario A	Scenario B
Highly Important Stressors			
2,3	Reduced staging and spawning habitat	Very low benefit	Very low benefit
1,4	SWP/CVP entrainment	High benefit	High benefit
2,3	Reduced rearing and outmigration habitat	Moderate benefit	Moderate benefit
1	Predation by non-natives	High benefit	High benefit
Moderately Important Stressors			
1	Exposure to toxics	Moderate adverse effect	Moderate adverse effect
1	Reduced genetic diversity/ integrity	No net effect	No net effect
1	Harvest	No net effect	No net effect
2,3	Increased water temperature	No net effect	No net effect

Notes:
1. See Appendix C for descriptions of stressors, stressor impact mechanisms, and stressor effects.

6.1.3.1 Criterion #1. Relative degree to which the Option would reduce species mortality attributable to non-natural mortality sources, in order to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species.

Predation by non-native species

Successful restoration of the Delta can promote benefits to native species at the expense of non-natives. Option 4 would allow 75% of the Delta to be potentially restored (Figure 1-5), the highest level among the four Options included in this assessment. Therefore, this Option is expected to have high benefits to Sacramento River salmonids by reducing the impacts of competition by non-native species, assuming that restoration will reduce the abundance of non-natives and/or enhance the survival and abundance of native species.

Entrainment

Under Option 4 all SWP and CVP diversions would occur from the Sacramento River through a positive barrier fish screen designed and operated specifically to avoid entrainment and impingement of juvenile salmon, steelhead, and other fish species. Removing the SWP and CVP exports from the south Delta under Option 4 would reduce the risk of salmonid entrainment by approximately 95%. This is based on the assumption that the positive barrier fish screen without a need for salvage will be more effective than the current louvers. Therefore, entrainment of juvenile Sacramento salmonids as a result of SWP or CVP export operations is expected to be substantially reduced under Option 4 when compared to base conditions.

Exposure to toxics

Dilution flows for toxic materials entering the Delta can be measured by Delta inflow and flow at Rio Vista. Relative to base conditions, flows at Rio Vista and total Delta inflows under Options 4 are moderately lower in both March and April (see Appendices G and H). This indicates that potential dilution of toxics from the San Joaquin River watershed or from the Delta would be moderately lower under Option 4 relative to base conditions resulting in a potential increase in salmonid exposure to toxics. Further, because the volume of water coming from the Sacramento River into the Delta would be reduced under Option 4, the contribution of the San Joaquin River water to water quality conditions within the Delta would be higher. Because San Joaquin River water is known to contain higher concentrations of toxics than Sacramento River water, this change would be expected to further increase the probability of salmonid exposure to toxics farther downstream. Therefore, overall, Option 4 would be expected to provide a moderate increase in the risk of salmonid exposure to toxics.

6.1.3.2 Criteria 2. Relative degree to which the Option would provide water quality and flow conditions necessary to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species.

Water quality changes that impact Sacramento River salmonids can be measured as differences in exposure to toxics, water temperature, and dissolved oxygen relative to base conditions. Flow changes that impact Sacramento River salmonids affect rearing habitat and access to

staging and spawning habitat. Option 2 is expected to result in a very low adverse decrease in water quality and flow related conditions relative to base conditions.

Exposure to Toxics

As discussed in Criterion 1, exposure to toxics is expected to moderately increase under Option 4.

Rearing habitat

The location of X_2 would be upstream by 0.2 km, which is a negligible adverse effect to salmonids. Model output indicates that both Rio Vista flows and total Delta outflow under Option 4 during March and April would be lower than base conditions for all water year types (see Appendices G and H). Chinook salmon that outmigrate during winter months (e.g., late fall-run Chinook salmon) experience similar lower flows at Rio Vista and total Delta outflows during this period. Overall, quality and accessibility of rearing habitat to Sacramento River salmonids would be reduced under Option 4.

Because residence time in the Central Delta is greatly increased under Option 4, there would be a higher probability of localized dissolved oxygen sags than under base conditions. The interaction between changes in residence times, phytoplankton production, and dissolved oxygen concentrations within the tidally dominated areas of the Delta are complex and the certainty of future predictions of changes in water quality is low.

Access to staging and spawning habitat

Under Option 4, less Sacramento River water would be directed into the Delta to maintain water quality standards. Also, there would be a more direct pathway of migration cues down the Sacramento River rather than diffused throughout the Delta. However, there would be a reduction in inflows due to the export of water at Hood. Therefore, there is expected to be a low increase in attraction flows and migration cues for both adult and juvenile salmonids.

6.1.3.3 Criterion #3. Relative degree to which the Option would increase habitat quality, quantity, accessibility, and diversity in order to enhance and sustain production (reproduction, growth, survival), abundance, and distribution; and to improve the resiliency of each of the covered species' populations to environmental change and variable hydrology.

Overall, Option 3 is expected to provide moderate increases in quality, quantity, diversity, and accessibility of habitat for Sacramento River salmonids.

Rearing habitat

Results of the hydrologic modeling indicate that there would be a negligible effect of Option 4 on X_2 location during the spring and, therefore, on the quantity, quality, and diversity of rearing habitat for juvenile salmonids. The reduction in net downstream flows is expected to cause a low reduction in survival of juvenile salmonids migrating towards rearing habitat. The proportion of the Delta available for restoration and enhancement of physical habitat and natural hydrology (Figure 1-5) would extend throughout the geographic range of salmonid

migration and rearing habitat within the Delta. Overall, Option 4 is expected to have a moderate beneficial effect on the quality, quantity, diversity, and accessibility to habitat for Central Valley Chinook salmon and steelhead.

Access to staging and spawning habitat

As described in Criterion 2, there is expected to be a low increase in attraction flows and migratory cues to spawning habitat under Option 4. Therefore, Option 4 is expected to have a very low benefit to spawning habitat of Sacramento River salmonids.

6.1.3.4 Criterion# 4. Relative degree to which the Option would increase food quality, quantity, and accessibility (e.g., phytoplankton, zooplankton, macro-invertebrates, forage fish) to enhance production (reproduction, growth, survival) and abundance for each of the covered fish species.

Juvenile Chinook salmon and steelhead forage on a variety of macroinvertebrates (e.g., copepods, amphipods) and small fish during their residency within the Delta. The abundance of these prey species varies in response to a number of factors that include availability of nutrients, organic carbon, phytoplankton and zooplankton production. Reduced food availability or quality, however, are not identified as important stressors for Sacramento River salmonids. Consequently, benefits of increasing food quantity and quality under the Options would not be expected to result in a population level response relative to base conditions.

6.1.3.5 Criterion #5. Relative degree to which the Option would reduce the abundance of non-native competitors and predators to increase native species production (reproduction, growth, survival), abundance and distribution for each of the covered fish species.

The degree to which Option 4 can reduce the adverse effects of non-native competitors and predators on Sacramento River salmon and steelhead can be approximated by determining the percentage of the Delta that would potentially be available for restoration and enhancement under this Option. Under Option 4 the potential area of the Delta that could be restored or enhanced is approximately 75% of the legal Delta (Figure 1-5). The amount of habitat available for restoration under Option 4 is more than double that available under Options 1, 2, or 3. The area within the Delta where restoration could potentially occur extends throughout nearly the entire geographic range of salmon and steelhead rearing and migration habitat within the Delta. As a result, Option 4 could provide a high benefit to salmonids by mitigating the adverse effects of non-native species.

6.1.3.6 Criterion #6. Relative degree to which the Option improves ecosystem processes in the BDCP planning area to support aquatic and associated habitats.

Under the range of operations and the potential opportunities to restore/enhance high quality aquatic habitat within the Delta habitat the effectiveness of Option 4 in improving ecosystem processes is considered to be high. These changes would be expected to improve ecosystem processes within the central and western regions of the Delta when compared to base conditions. In addition, the ability to divert water directly from the Sacramento River at Hood while eliminating the export operations within the south Delta would be expected to substantially improve the hydrodynamics of the Delta and improve the quality of habitat

available for Sacramento River salmonids. Under these operating conditions Option 4 offers the opportunity to improve the processes affecting habitat conditions within the Delta (e.g., providing net westerly flows, reducing or eliminating reverse flow conditions, etc.). These potential changes to the estuarine processes within the Delta are expected to benefit Sacramento River salmonids and other species. It is uncertain, however, if increasing the proportion of lower quality San Joaquin River water present in the Delta (a function of reducing Sacramento River inflow and eliminating export of San Joaquin River water from the Delta) into the central Delta would impair ecosystem processes.

6.1.3.7 Criterion #7. Relative degree to which the Option can be implemented within a timeframe to meet the near-term needs of each covered fish species (post BDCP authorization).

Habitat restoration under Option 4 can be initiated immediately following authorization of the BDCP and thus could be implemented in a manner that would meet the near term needs of Sacramento River salmonids. The implementation period for implementation of Option 4 is the same as the other Options.

6.1.4 San Joaquin River Salmonids

Based on the evaluation presented below of the expected performance of Option 4 for addressing important San Joaquin River salmonid stressors, Option 4 would be expected to have a moderate beneficial effect on San Joaquin River salmonid production, distribution, and abundance relative to base conditions when operated to meet water supply objectives (Scenario A). If water supply exports are reduced (Scenario B), Option 2 would be expected to provide a low beneficial effect on Sacramento River salmonid production, distribution, and abundance relative to base conditions.

Table 6-5 and 6-6 summarizes the expected effects of implementing Option 4 under Scenarios A and B on important delta smelt stressors relative to base conditions.

Table 6-5. Summary of Expected Effects of Option 4 on Highly and Moderately Important San Joaquin River Chinook Salmon Stressors

Applicable Criteria	Stressor[1]	Option Effects on Important Species Stressors Relative to Base Conditions	
		Scenario A	Scenario B
Highly Important Stressors			
2,3	Reduced staging and spawning habitat	Low benefit	Low benefit
2,3	Reduced rearing and outmigration habitat	Moderate benefit	Moderate benefit
1,2	Exposure to toxics	Moderate adverse effect	Moderate adverse effect
1,2	Predation by non-natives	High benefit	High benefit

Table 6-5. Summary of Expected Effects of Option 4 on Highly and Moderately Important San Joaquin River Chinook Salmon Stressors (continued)

Applicable Criteria	Stressor[1]	Option Effects on Important Species Stressors Relative to Base Conditions	
		Scenario A	Scenario B
Moderately Important Stressors			
1	Reduced genetic diversity/ integrity	No net effect	No net effect
1	Harvest	No net effect	No net effect
1,4	SWP/CVP entrainment	High benefit	High benefit
2,3	Increased water temperature	No net effect	No net effect

Notes:
1. See Appendix C for descriptions of stressors, stressor impact mechanisms, and stressor effects.

Table 6-6. Summary of Expected Effects of Option 4 on Highly and Moderately Important San Joaquin River Steelhead Stressors

Applicable Criteria	Stressor[1]	Option Effects on Important Species Stressors Relative to Base Conditions	
		Scenario A	Scenario B
Highly Important Stressors			
3	Reduced staging and spawning habitat	Low benefit	Low benefit
3	Reduced rearing and outmigration habitat	Moderate benefit	Moderate benefit
1	Exposure to toxics	Moderate adverse effect	Moderate adverse effect
1	Reduced genetic diversity/ integrity	No net effect	No net effect
1	Predation by non-natives	High benefit	High benefit
Moderately Important Stressors			
1,3,4,5	SWP/CVP entrainment	High benefit	High benefit
1	Harvest	No net effect	No net effect
1	Increased water temperature	No net effect	No net effect

Notes:
1. See Appendix C for descriptions of stressors, stressor impact mechanisms, and stressor effects.

6.1.4.1 Criterion #1. Relative degree to which the Option would reduce species mortality attributable to non-natural mortality sources, in order to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species.

Overall, Option 4 is expected to contribute to a high level of reduction in non-natural mortality to San Joaquin River Chinook salmon and steelhead.

Predation by non-native species

Restoration of the Delta, if designed properly, can reduce conditions for non-native predators to the benefit of San Joaquin River salmonids. Option 4 would allow 75% of the Delta to be potentially restored (Figure 1-5), the highest level among the four Options included in this assessment. Therefore, this Option is expected to provide a high benefit to San Joaquin River Chinook salmon. The benefit to steelhead, because they typically outmigrate at larger sizes that are less vulnerable to predation, is expected to be slightly lower, but still considered high under this analysis.

Entrainment

Under Option, 4 all SWP and CVP diversions would be made from the Sacramento River using a state-of-the-art positive barrier fish screen. Fish screens designed to meet the CDFG, USFWS, and NMFS criteria have proven to be effective in substantially reducing the risk of entrainment or impingement to juvenile and adult fish, such as salmon and steelhead. Based on the proposed location of the diversion at Hood, San Joaquin River salmonids would not be expected to occur within the vicinity of the diversion. Under Option 4 the risk of San Joaquin River salmon and steelhead entrainment losses as a direct result of SWP and CVP export operations would be eliminated. Therefore, this Option would provide a high reduction in mortality associated with entrainment.

Exposure to toxics

As discussed under Criterion 3 below, Option 4 is expected to cause a moderate increase in the exposure risk to toxics of San Joaquin River salmonids relative to base conditions.

6.1.4.2 Criterion #2. Relative degree to which the Option would provide water quality and flow conditions necessary to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species.

Overall, Option 4 would be expected to provide a very low adverse effect to water quality and flow conditions for San Joaquin River salmonids.

Exposure to toxics

Hydrologic modeling output indicates that, relative to base conditions, flows at Rio Vista under Option 4 would typically be lower in all water years in both March and April (Table ____). Delta inflows would also be lower under Option 4 relative to base conditions (Table ___). This indicates that dilution inflows of toxics would be moderately lower under Option 4, resulting in a potential increase in salmonid exposure to elevated concentrations of toxics. Further, because the volume of water coming from the Sacramento River into the Delta would be reduced under Option 4, the contribution of the San Joaquin River water to the Delta would be higher. Because San Joaquin River water is known to contain higher concentrations of toxics than Sacramento River water, this change would be expected to further increase the probability of San Joaquin River salmonid exposure to toxics. Therefore, overall, Option 4 would be expected to cause a moderate increase in the risk of salmonid exposure to toxics.

Rearing habitat

The location of X_2 would be upstream by 0.2 km, which is a negligible adverse effect to salmonids. Model output indicates that both Rio Vista flows and total Delta outflow, which help transport outmigrating salmon downstream to rearing habitat, under Option 4 during March and April would be lower than base conditions for all water year types (Table ____). The potential effects of reduced flows through the Delta on the survival of juvenile salmon and steelhead under Option 4, with the removal of the export facilities in the south Delta, is unknown. Overall, water quality and flow conditions under Option 4 would cause a low adverse effect to the quality and accessibility of rearing habitat to San Joaquin River salmonids.

SWP and CVP operations and the associated hydrologic conditions expected to occur within the Delta under Option 4 are not expected to result in dissolved oxygen depression greater than baseline conditions. The assumption that San Joaquin River flows would be the same under Option 4 as base conditions suggests that this Option would not affect localized depressions in dissolved oxygen levels such as those observed in the Stockton ship channel. A possible exception would be the accumulation of high algal concentrations within the Delta resulting from increased nutrient concentrations, increased residence times, and reduced flushing. The Delta would continue to experience tidal flushing as well as the net westerly flow from the tributaries. The possibility that dissolved oxygen concentrations within Delta channels would be reduced to adverse levels under Option 4 is uncertain.

Access to staging and spawning habitat

Because the Options evaluated in this analysis assumed that San Joaquin River flows would be the same as base conditions under all Options no change in flow-survival (e.g., temperature related) or attraction flow relationships would be expected under any of the Options. Under Option 4, however, the location of the diversion on the Sacramento River would be expected to result in slightly improved hydrologic conditions (e.g., net westerly flows) within the Delta channels and improve attraction flows and migration cues for salmonids migrating into and out of the San Joaquin River.

6.1.4.3 Criterion #3. Relative degree to which the Option would increase food quality, quantity, and accessibility (e.g., phytoplankton, zooplankton, macro-invertebrates, forage fish) to enhance production (reproduction, growth, survival) and abundance for each of the covered fish species.

Overall, Option 4 is expected to provide a high level of benefit to San Joaquin River salmonid habitats relative to base conditions.

Rearing habitat

Results of the hydrologic modeling indicate that there would be a negligible effect of Option 4 on X_2 location during the spring and, therefore, on the quantity, quality, and diversity of rearing habitat for juvenile salmonids.

The reduction in net downstream flows is expected to cause a low reduction in survival of juvenile salmonids migrating towards rearing habitat, however there is a high degree of

uncertainty in the flow-survival relationships that may occur under Option 4 operations. The relocation of SWP and CVP diversions to the Sacramento River would result in an improvement in Delta flow patterns (e.g., avoid reverse flows) that would benefit juvenile and adult salmonid migration through the Delta.

Under Option 4, a large portion (~75%) of the Delta is potentially available for restoration/enhancement (Figure 1-5) including areas located along the lower San Joaquin River and the eastern region of the Delta that would not be included under Options 1, 2, or 3. These habitat improvements, including the potential to increase seasonally inundated floodplain habitat within the southern and central Delta would be expected to offer substantially improved conditions for San Joaquin River salmonids when compared to base conditions or the other three Options evaluated. In addition, because SWP and CVP exports would no longer occur in the south Delta, hydrodynamic conditions would improve throughout the region and the risk of entrainment at the south Delta export facilities would be eliminated, thereby increasing opportunities for high quality habitat restoration. The areas where restoration would potentially occur encompass virtually the entire geographic distribution of the juvenile salmonids within the Delta. Therefore, Option 4 would provide the highest opportunity for restoration among the four Options evaluated.

Access to staging and spawning habitat

As discussed under Criterion 3, access to spawning habitat would not change among Options.

6.1.4.4 Criterion #4. Relative degree to which the Option would increase food quality, quantity, and accessibility (e.g., phytoplankton, zooplankton, macro-invertebrates, forage fish) to enhance production (reproduction, growth, survival) and abundance for each of the covered fish species.

Juvenile Chinook salmon and steelhead forage on a variety of macroinvertebrates (e.g., copepods, amphipods) and small fish during their residency within the Delta. The abundance of these prey species varies in response to a number of factors that include availability of nutrients, organic carbon, phytoplankton and zooplankton production. Reduced food availability or quality, however, are not identified as important stressors for San Joaquin River salmonids. Consequently, benefits of increasing food quantity and quality under the Options would not be expected to result in a population level response relative to base conditions.

6.1.4.5 Criterion #5. Relative degree to which the Option would reduce the abundance of non-native competitors and predators to increase native species production (reproduction, growth, survival), abundance and distribution for each of the covered fish species.

The degree to which Option 4 can reduce the adverse effects of non-native competitors and predators on San Joaquin River salmon and steelhead can be approximated by determining the percentage of the Delta that would potentially be available for restoration/enhancement under this Option. Under Option 4 the potential area of the Delta that could be restored or enhanced is approximately 75% of the legal Delta (Figure 1-5). The amount of habitat available for restoration under Option 4 is more than double that available under Options 1, 2, or 3. The area within the Delta where restoration could potentially occur extends throughout nearly the entire geographic range of salmon and steelhead rearing and migration habitat within the Delta. As a

result, Option 4 could provide a high benefit to salmonids by mitigating the adverse effects of non-native species.

6.1.4.6 Criterion #6. Relative degree to which the Option improves ecosystem processes in the BDCP planning area to support aquatic and associated habitats.

Under the range of operations and the potential opportunities to restore/enhance high quality aquatic habitat within the Delta habitat the effectiveness of Option 4 in improving ecosystem processes is considered to be high. These changes would be expected to provide the potential to improve ecosystem processes throughout the Delta when compared to base conditions. In addition, the ability to divert water directly from the Sacramento River at Hood while eliminating the export operations within the south Delta would be expected to substantially improve the hydrodynamics of the Delta and improve the quality of habitat available for San Joaquin River salmonids. Under these operating conditions Option 4 offers the opportunity to improve the processes affecting habitat conditions within the Delta (e.g., providing net westerly flows, reducing or eliminating reverse flow conditions, etc.). These potential changes to the estuarine processes within the Delta are expected to benefit San Joaquin River salmonids and other species. It is uncertain, however, if increasing the proportion of low quality San Joaquin River water present in the Delta (a function of reducing Sacramento River inflow and eliminating export of San Joaquin River water from the Delta) into the central Delta would impair ecosystem processes.

6.1.4.7 Criterion #7. Relative degree to which the Option can be implemented within a timeframe to meet the near-term needs of each covered fish species (post BDCP authorization).

Habitat restoration under Option 4 can be initiated immediately following authorization of the BDCP and thus could be implemented in a manner that would meet the near term needs of San Joaquin River salmonids. The implementation period for implementation of Option 4 is the same as the other Options.

6.1.5 Sturgeon

Based on the evaluation presented below of the expected performance of Option 4 for addressing important green and white sturgeon stressors, Option 4 would be expected to have a moderate beneficial effect on green and white sturgeon production, distribution, and abundance relative to base conditions when operated to meet water supply objectives (Scenario A). If water supply exports are reduced (Scenario B), Option 4 would be expected to provide a similar level of benefit for sturgeon production, distribution, and abundance relative to base conditions.

Stressors that affect sturgeon are presented in Figures 2-7 and 2-8 and are described in Appendix C. The effect of these stressors on the green and white sturgeon populations vary among years in response to environmental conditions (e.g., seasonal hydrology) and may also interact with each other in additive or synergistic ways. The effects of these stressors include both the incremental contribution of a stressor to the population as well as the cumulative effects of multiple stressors over time. The assessment of Option 4 evaluates the degree to which Option 4 would be expected to address these stressors.

Tables 6-7 and 6-8, respectively, summarize the expected effects of implementing Option 1 under Scenarios A and B on important sturgeon stressors relative to base conditions.

Table 6-7. Summary of Expected Effects of Option 4 on Highly and Moderately Important Green Sturgeon Stressors

Stressors[1]	Applicable Criteria	Option Effects on Important Species Stressors Relative to Base Conditions	
		Scenario A	Scenario B
Highly Important Stressors			
Reduced spawning habitat	3	No net effect	No net effect
Exposure to toxics	1,2,3	Moderate adverse effect	Moderate adverse effect
Harvest	1	No net effect	No net effect
Moderately Important Stressors			
Reduced rearing habitat	1,2,3	Moderate benefit	Moderate benefit
Increased water temperature (upstream)	1,2,3	No net effect	No net effect
Predation	1,3	No net effect	No net effect
Reduced turbidity	1,2,3	No net effect	No net effect

Notes:
1. See Appendix C for descriptions of stressors, stressor impact mechanisms, and stressor effects.

Table 6-8. Summary of Expected Effects of Option 4 on Highly and Moderately Important White Sturgeon Stressors

Stressors[1]	Applicable Criteria	Option Effects on Important Species Stressors Relative to Base Conditions	
		Scenario A	Scenario B
Highly Important Stressors			
Harvest	1	No net effect	No net effect
Reduced spawning habitat	3	No net effect	No net effect
Exposure to toxics	1,2,3	Moderate adverse effect	Moderate adverse effect
Moderately Important Stressors			
Reduced rearing habitat	1,2,3	Moderate benefit	Moderate benefit
Increased water temperature (upstream)	1,2,3	No net effect	No net effect
Predation	1,3	No net effect	No net effect
Reduced turbidity	1,2,3	No net effect	No net effect

Notes:
1. See Appendix C for descriptions of stressors, stressor impact mechanisms, and stressor effects.

Harvest, reduced spawning habitat, predation, reduced turbidity, and increased water temperatures are not important stressors that would be affected by or affected differently (i.e., harvest, reduced spawning habitat) under the Options and, therefore, are not described in the criteria evaluations below (see Table 2-3 and Appendix C). These stressors could only be addressed through changes in regulation and law enforcement (for harvest) or through conservation actions implemented outside of the planning area. Any effects within the planning area of the Options on the non-harvest stressors described above would not be expected to have any benefits to sturgeon at the population level. As described in Table 2-3, the ability to address harvest and reduced spawning habitat within the planning area would be the same among the Options. Consequently, these stressors are initially identified under the applicable criteria below, but are not evaluated under the criteria.

6.1.5.1 Criterion #1. Relative degree to which the Option would reduce species mortality attributable to non-natural mortality sources, in order to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species.

Based on the following evaluation of Option 4 effects on applicable green and white sturgeon stressors, Option 4 is expected to provide a very low increase in the risk for non-natural mortality of sturgeon.

Exposure to Toxics

Exposure of green and white sturgeon to toxic substances can result in mortality. The effects of Option 4 on exposure to toxics are evaluated under Criteria #2 and #4 below. As described in the Criteria #2 and #4 evaluations, Option 4 would be expected to result in a moderate adverse effect on the exposure of green and white sturgeon to toxics.

6.1.5.2 Criterion #2. Relative degree to which the Option would provide water quality and flow conditions necessary to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species.

Based on the following evaluation of Option 4 effects on applicable green and white sturgeon stressors, Option 4 is expected to provide a very low adverse effect for water quality and flow conditions that support green and white sturgeon relative to base conditions.

Exposure to toxics

Based on how Option 4 would be expected to affect Sacramento River inflow and total Delta inflows relative to modeling results for base conditions and the Options, dilution flows under Option 4 would be lower relative to base conditions and could have a moderate adverse effect on the exposure of sturgeon to toxics (see Appendices G and H).

Reduced Rearing Habitat

Under Option 4, X_2 position would move marginally upstream (0.2 km) relative to base conditions (see Appendices F and H), indicating that the extent of available rearing habitat could be reduced relative to base conditions. In addition, Option 4 would be expected to

improve westerly flows through the central Delta as a migration cue for both juvenile and adult sturgeon migration. The effect of these changed hydraulic conditions is unknown, because the frequency of occurrence of green or white sturgeon juveniles and adults within the eastern region of the Delta is unknown. In general, improvement in the flow patterns within the Delta under Option 4 (e.g., net westerly flows, avoid reverse flow conditions, increased residence times, etc.) are expected to benefit habitat conditions for juvenile and adult sturgeon, their food resources, and other fish species.

6.1.5.3 Criterion #3. Relative degree to which the Option would increase habitat quality, quantity, accessibility, and diversity in order to enhance and sustain production (reproduction, growth, survival), abundance, and distribution; and to improve the resiliency of each of the covered species' populations to environmental change and variable hydrology.

Within the planning area, green and white sturgeon habitat conditions are governed by hydrodynamic conditions and the extent and quality of habitat within the planning area. Under Option 4, these conditions relative to base conditions would be affected by the conveyance configuration of Option 4 and the opportunities for restoration of physical habitat that could be sited within Suisun Bay and Marsh and throughout the Delta planning area, which represents approximately 75% of the planning area.

Based on the following evaluation of Option 4 effects on applicable green and white sturgeon stressors, Option 4 are expected to provide moderate habitat benefits for green sturgeon relative to base conditions.

Exposure to Toxics

As described under Criterion #2 above, Option 4 could have a moderate adverse effect on the risk for exposure of sturgeon to toxics relative to base conditions. A major source for bioaccumulation of selenium in sturgeon is consumption of non-native *Corbula* and *Corbicula*, which capture selenium from Delta waters. Restoration of aquatic shallow subtidal and intertidal habitats could create conditions that favor the production of alternative prey (e.g., bay shrimp) that reduce the risk of bioaccumulation of materials such as selenium for juvenile and adult sturgeon. The potential success of reducing the risk of toxics on sturgeon through habitat improvements and increased production of alternative prey resources is uncertain. Under Option 4, habitat could potentially be restored within Suisun Bay and Marsh and approximately 75% of the Delta to provide high quality aquatic habitat under this Option (Figure 1-5), which encompasses a larger proportion of the rearing range of green and white sturgeon than restoration that could be implemented under the other Options. Consequently, relative to base conditions and the other Options, Option 4 would be expected to provide a moderate benefit for improving green and white sturgeon rearing habitat.

Reduced Rearing Habitat

The primary impact mechanism believed to affect the extent of rearing habitat and rearing habitat conditions is the reclamation of historical aquatic subtidal and intertidal habitats and channelization of river channels. Under Option 4, habitat could be restored within Suisun Bay and Marsh and approximately 75% of the Delta to provide high quality aquatic habitat under

this Option (Figure 1-5), which encompasses a larger proportion of the rearing range of green and white sturgeon than restoration that could be implemented under the other Options. Consequently, relative to base conditions and the other Options, Option 4 would be expected to provide a moderate benefit for green and white sturgeon rearing habitat.

6.1.5.4 Criterion #4. Relative degree to which the Option would increase food quality, quantity, and accessibility (e.g., phytoplankton, zooplankton, macro-invertebrates, forage fish) to enhance production (reproduction, growth, survival) and abundance for each of the covered fish species.

Based on the following evaluation of Option 4 effects on applicable green and white stressors, Option 4 is expected to provide moderate food supply benefits for green and white sturgeon relative to base conditions.

Exposure to Toxics

As described under Criterion #3 above, restoration of rearing habitat could reduce the relative importance of non-native *Corbula* and *Corbicula* as a primary food resource for sturgeon thus improving the quality of food for sturgeon by reducing their exposure to selenium. Relative to base conditions and the other Options, Option 4 would be expected to provide moderate benefits for green and white sturgeon food supply.

6.1.5.5 Criterion #5. Relative degree to which the Option would reduce the abundance of non-native competitors and predators to increase native species production (reproduction, growth, survival), abundance and distribution for each of the covered fish species.

Predation in the form of illegal and legal harvest would not be changed under any of the Options from base conditions.

6.1.5.6 Criterion #6. Relative degree to which the Option improves ecosystem processes in the BDCP planning area to support aquatic and associated habitats.

Based on the proportion of the planning area available for potential restoration under Option 4 relative to the other Options and modeling results for hydraulic residence time (see Appendix H), Option 4 would be expected to provide a high beneficial improvement in ecosystem function relative to base conditions.

Under the range of operations and the potential opportunities to restore/enhance high quality aquatic habitat within the Delta habitat the effectiveness of Option 4 in improving ecosystem processes is considered to be high. These changes would be expected to improve ecosystem processes throughout the Delta when compared to base conditions. In addition, the ability to divert water directly from the Sacramento River at Hood while eliminating the export operations within the south Delta would be expected to substantially improve the hydrodynamics of the Delta and improve the quality of habitat available for juvenile and adult green and white sturgeon. Under these operating conditions Option 4 offers the opportunity to improve the processes affecting habitat conditions within the Delta (e.g., providing net westerly flows, reducing or eliminating reverse flow conditions, etc.). These potential changes to the estuarine processes within the Delta are expected to benefit sturgeon and other species. It is

uncertain, however, if increasing the proportion of low quality San Joaquin River water present in the Delta (a function of reducing Sacramento River inflow and eliminating export of San Joaquin River water from the Delta) into the central Delta would impair ecosystem processes.

6.1.5.7 Criterion #7. Relative degree to which the Option can be implemented within a timeframe to meet the near-term needs of each covered fish species (post BDCP authorization).

In the near-term, until construction of Option 4 conveyance features and facilities is completed, Option 4 would use the existing conveyance facilities to meet water supply objectives. As for Option 1, implementation of physical habitat restoration under Option 4 in the north and west Delta can be initiated immediately following authorization of the BDCP and thus could be implemented in a manner that would meet the near term needs of sturgeon.

6.1.6 Splittail

Based on the evaluation presented below of the expected performance of Option 4 for addressing important splittail stressors, Option 4 would be expected to have a high beneficial effect on splittail production, distribution, and abundance relative to base conditions when operated to meet water supply objectives (Scenario A). If water supply exports were reduced (Scenario B), Option 4 would also be expected to provide a high beneficial effect on splittail production, distribution, and abundance relative to base conditions. Option 4 would be expected to provide a greater level of benefit for splittail than the other Options.

Table 6-9 summarizes the expected effects of implementing Option 4 under Scenarios A and B on important splittail stressors relative to base conditions.

Table 6-9. Summary of Expected Effects of Option 4 on Highly and Moderately Important Splittail Stressors

Applicable Criteria	Stressor[1]	Option Effects on Important Species Stressors Relative to Base Conditions	
		Option 3A	Option 3B
Highly Important Stressors			
2,3	Reduced juvenile rearing/adult habitat	High benefit	High benefit
2,3	Reduced spawning/larval rearing habitat	High benefit	High benefit
1,4	Reduced food	High benefit	High benefit
1,2	Exposure to toxics	Moderate adverse effect	No effect
Moderately Important Stressors			
1,5	Predation by non-natives	High benefit	High benefit
1,3,4,5	SWP/CVP entrainment[2]	High benefit	High benefit
1	Harvest	No net effect	No net effect

Notes:

1. See Appendix C for descriptions of stressors, stressor impact mechanisms, and stressor effects.
2. It is recognized that the risk of entrainment at the SWP and CVP export facilities may be a high level stressor to splittail in some years and a very low level stressor in other years, for purposes of the analysis the risk of splittail entrainment under each of the Options has been characterized, on average, as a moderate level stressor to the population.

6.1.6.1 Criterion #1. Relative degree to which the Option would reduce species mortality attributable to non-natural mortality sources, in order to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species.

Based on the following evaluation of Option 4 effects on applicable splittail stressors, Option 4 is expected to provide high benefits for splittail by reducing the effects of non-natural sources of mortality relative to base conditions.

Reduced Food Availability

Habitat conditions can affect the availability and quality of splittail food. The effects of Option 4 on splittail food availability are evaluated under Criterion #4 below. As described in the Criterion #4 evaluation, Option 4 would be expected to provide a high beneficial effect on food supply for the splittail relative to base conditions.

Exposure to Toxics

The effects of Option 4 on exposure to toxics are evaluated under Criterion #2 below. As described in the Criterion #2 evaluation, Option 4 would be expected to have a moderate adverse effect on the risk of exposure of splittail to toxics. It is uncertain, however, if the potential increase in concentrations of toxics in the central Delta would adversely affect splittail.

Predation

Under Option 4, approximately 75% of the Delta would potentially be available for restoration/enhancement (Figure 1-5), which, if designed properly, would reduce the potential adverse impacts of predation by non-natives. This entire area would be located within the geographic range of splittail throughout the Delta. The proportion of the planning area within which habitat could potentially be implemented is greater under Option 4 than under any of the other Options. Habitat restoration under Option 4 would be expected to provide a high benefit for potentially reducing predation impacts relative to base conditions and the other Options. However, there is a high degree of uncertainty regarding the biological response of splittail, other native fish and macroinvertebrate species, and non-native species to large-scale habitat restoration/enhancement within the Delta.

Entrainment by CVP/SWP Facilities

Under Option 4, all SWP and CVP diversions would occur from the Sacramento River near Hood. Risk for entrainment of splittail at the Hood intake facility would be minimal because the intake would be equipped with a positive barrier fish screen that would be expected to be highly effective in reducing the vulnerability of splittail to entrainment. Removing the SWP and CVP exports from the south Delta under Option 4 would be expected to virtually eliminate the risk of splittail entrainment losses as a result of export operations. Based on this assessment, entrainment of splittail as a result of SWP or CVP export operations is expected to be nearly eliminated under Option 4 relative to base conditions.

6.1.6.2 Criterion #2. Relative degree to which the Option would provide water quality and flow conditions necessary to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species.

Based on the following evaluation of Option 4 effects on applicable splittail stressors, Option 4 is expected to have a low adverse effect on water quality and flow conditions that support splittail relative to base conditions.

Exposure to toxics

Modeling results indicate that Option 4 would be expected to reduce dilution flows relative to base conditions, thus potentially increasing concentrations of toxics (see Appendices F and H). Furthermore, because the volume of water coming from the Sacramento River into the Delta would be reduced under Option 4, the contribution of the San Joaquin River to water quality conditions within the Delta will be higher. Because San Joaquin River water is known to contain higher concentrations of toxics than Sacramento River water, Option 4 could increase the risk of exposing splittail to toxics. Although the effects of toxics on splittail are uncertain, Option 4 has the potential for having a moderate adverse effect on splittail by increasing the exposure of delta smelt to higher concentrations of toxics. Under Option 4, however, there are potential opportunities to restore intertidal and subtidal wetlands in the south Delta that could filter toxics from the San Joaquin River before it discharges into the central Delta, which would reduce the likelihood for toxic effects on splittail.

Reduced Rearing Habitat

Sacramento River inflows during March and April under Option 4 that facilitate the downstream movement of juvenile splittail are expected to be lower relative to base conditions. Expected changes in peak Delta inflows during January through March indicate that Option 4 would have a lower probability of floodplain inundation relative to base conditions in wetter years (see Appendices F and H). The potential restoration of rearing habitats as described under Criterion #3, however, would be expected to improve rearing habitat conditions. Consequently, overall Option 4 would be expected to have high beneficial effects on rearing habitat conditions relative to base conditions.

Reduced Spawning/Larval Rearing Habitat

Expected changes in peak Delta inflows during January through March indicate that, under Option 4, there would be a lower probability of floodplain inundation during wetter years relative to base conditions (see Appendices F and H). The potential restoration of spawning/larval rearing habitats as described under Criterion #3, however, would be expected to improve spawning/larval rearing habitat conditions. Consequently, overall Option 4 would be expected to have high beneficial effects on rearing habitat conditions relative to base conditions.

6.1.6.3 Criterion #3 Relative degree to which the Option would increase habitat quality, quantity, accessibility, and diversity in order to enhance and sustain production (reproduction, growth, survival), abundance, and distribution; and to improve the resiliency of each of the covered species' populations to environmental change and variable hydrology.

Based on the following evaluation of Option 4 effects on applicable splittail stressors, Option 4 is expected to provide high benefits relative to habitat conditions for splittail.

Within the planning area, splittail habitat conditions are governed by hydrodynamic conditions and the extent and quality of habitat. Under Option 4, these conditions relative to base conditions would be affected by the conveyance configuration of Option 4 and the opportunities for restoration of physical habitat that could be sited at locations throughout the Delta extending over approximately 75% of the planning area.

Reduced Rearing and Spawning Habitat

Under Option 4, habitat could potentially be restored within Suisun Bay and Marsh and approximately 75% of the Delta to provide high quality shallow aquatic subtidal and intertidal habitat (Figure 1-5), which encompasses a larger proportion of the splittail spawning and rearing range than restoration that could be implemented under the other Options. In addition, substantial increases in hydraulic residence time under Option 4 also provide for lower velocity habitats that are expected to be more suitable for splittail relative to base conditions. In addition, operations under Option 4 would contribute directly to restoring natural flow patterns within the Delta channels, reducing water velocities, increasing residence times, and avoiding reverse flows, which are all expected to contribute to improved habitat conditions. Consequently, relative to base conditions and the other Options, Option 4 would be expected to provide a high benefit for splittail rearing and spawning habitat.

Reduced Food Availability

Habitat conditions can affect the availability and quality of splittail food. The effects of Option 4 on splittail food availability are evaluated under Criterion #4 below. As described in the Criterion #4 evaluation, Option 4 would be expected to provide a high beneficial effect on food supply for the splittail relative to base conditions.

6.1.6.4 Criterion #4 Relative degree to which the Option would increase food quality, quantity, and accessibility (e.g., phytoplankton, zooplankton, macro-invertebrates, forage fish) to enhance production (reproduction, growth, survival) and abundance for each of the covered fish species.

Overall, Option 4 would be expected to provide high benefits for improving food supply for splittail.

Reduced Food Availability

Option 4 could decrease the frequency, duration, and extent of seasonally inundated floodplain habitat within the Sacramento or San Joaquin rivers, which could reduce food availability in

those areas in some years. Hydraulic residence would be substantially increased in the central Delta and would be expected to substantially increase phytoplankton, zooplankton, and macroinvertebrate production within the Delta relative to base conditions. Restoration of shallow subtidal and intertidal habitats under Option 4 would also be expected to improve food supply. Consequently, Option 4 would be expected to provide a high benefit for splittail food supply.

The habitat restoration that could be implemented under Option 4 would all be located within the geographic range of splittail and could create conditions that disfavor non-native species that indirectly or directly affect food abundance (e.g., overbite clam (*Corbula*), threadfin shad), thereby improving food availability for splittail relative to base conditions (Figure 1-5). The potential opportunity for habitat restoration is expected to improve food availability relative to base conditions and the other Options.

Option 4 would be expected to provide a high beneficial increase in food availability by eliminating the export of nutrients and organic material that support primary and secondary production by eliminating SWP/CVP exports from the south Delta. In addition, under Option 4, water with high nutrient loads from the San Joaquin River would no longer be subject to exports as under base conditions and the resulting increased nutrient loads, in combination with increased residence times, would be expected to stimulate phytoplankton and zooplankton production.

6.1.6.5 Criterion #5. Relative degree to which the Option would reduce the abundance of non-native competitors and predators to increase native species production (reproduction, growth, survival), abundance and distribution for each of the covered fish species.

Based on the following evaluation of Option 4 effects on applicable splittail stressors, Option 4 is expected to provide high benefits for splittail relative to the effects of non-native competitors and predators.

Option 4 could reduce the effects of non-native competitors and predators on splittail primarily through restoration of intertidal and shallow subtidal aquatic habitats at locations distributed throughout the Delta. For reasons described above, Option 4 would be expected to provide a high beneficial effect by reducing the impacts of populations of non-native food competitors relative to base conditions. Additionally, restoration of net westerly flows would restore Delta hydrodynamics to a more natural condition relative to base conditions and the other Options, which may create habitat conditions unfavorable for some non-native species. Although the ability to control non-native species by varying hydrodynamic and salinity conditions in the Delta is uncertain, Option 4 provides a greater opportunity for doing so than under Options 1 and 2, but somewhat less than Option 3.

6.1.6.6 Criterion #6. Relative degree to which the Option improves ecosystem processes in the BDCP planning area to support aquatic and associated habitats.

Based on the proportion of the planning area available and suitable for potential restoration under Option 4 relative to the other Options and modeling results for hydraulic residence time (see Appendix H), Option 4 would be expected to provide a high beneficial improvement in ecosystem function relative to base conditions.

Based on the large proportion of the Delta available for restoring natural hydrology and for restoring and enhancing high quality aquatic habitat, the effectiveness of Option 4 in improving ecosystem processes is considered to be high. These changes would be expected to improve ecosystem processes throughout the Delta when compared to base conditions. In addition, the ability to divert water from the Sacramento River at Hood while eliminating the export operations in the south Delta would be expected to substantially improve the hydrodynamics of the Delta and improve the quality of habitat available for splittail. Under these operating conditions Option 4 offers the opportunity to improve the processes affecting habitat conditions within the Delta (e.g., providing net westerly flows, reducing or eliminating reverse flow conditions, etc.). These potential changes to the estuarine processes within the Delta are expected to benefit splittail and other species. It is uncertain, however, if increasing the proportion of lower quality San Joaquin River water present in the Delta (a function of reducing Sacramento River inflow and eliminating export of San Joaquin River water from the Delta) into the central and western Delta would impair ecosystem processes.

6.1.6.7 Criterion #7. Relative degree to which the Option can be implemented within a timeframe to meet the near-term needs of each covered fish species (post BDCP authorization).

In the near-term, until construction of Option 4 conveyance features and facilities is completed, this Option would use the existing conveyance facilities to meet water supply objectives. Similar to Option 1, implementation of physical habitat restoration under Option 4 in the north and west Delta can be initiated immediately following authorization of the BDCP and thus could be implemented in a manner that would meet the near term needs of juvenile and adult splittail.

6.2 PLANNING CRITERIA

6.2.1.1 Criterion #8: Relative degree to which the Option allows covered activities to be implemented in a way that meets the goals and purposes of those activities

Overall, Option 4 is anticipated to have a greater ability to meet CVP/SWP water supply goals than Options 1 and 2 and a lesser ability than Option 3.

Hydrodynamic modeling results indicate that the ability of Option 4 to achieve the water delivery reliability and facility operation goals of the CVP/SWP would be less than Option 3 and Option 1 (Scenario A). However, Option 1 water supply reliability is expected to be less than that modeled under Scenario 1A because of regulatory restrictions imposed on pumping in the south Delta. Option 4 may, therefore, provide higher supply reliability than Option 1. Hydrodynamic modeling results indicate higher supply reliability under Option 4 than under Option 1 (Scenario B) and Option 2 (Figure 3-1).

Model simulations for Option 4 have indicated the potential for reduced CVP/SWP exports in the range of 100 to 800 TAF/YR as compared to current conditions, depending on the level of Rio Vista flow requirements, X_2 objectives, and salinity requirements. While CVP/SWP export reliability approaches current conditions under the less restrictive end of the range (Scenario A), significant upstream versus downstream tradeoffs were identified. Modeled Rio Vista flow requirements, in particular, caused excessive drawdown of upstream storage under this Option.

Several iterations of Rio Vista criteria and refined operations were modeled to protect upstream storage during critical periods while simultaneously achieving Rio Vista requirements. The final model simulations are the result of this iterative approach, but still exhibit decreased storage during dry periods. The upstream versus downstream tradeoffs demonstrate a potential decrease in operational flexibility of the SWP and CVP system operations overall. Further analysis of this tradeoff and further refinements in operating criteria should be considered if this Option is carried forward.

Export water quality would be significantly improved under Option 4 as compared to current conditions and Options 1, Option 2, and Option 3 (Figure 3-2). The export water quality is equivalent to Sacramento River at Hood quality, which is significantly higher quality than that from the south Delta under current conditions and any other Option considered in this evaluation.

6.2.1.2 Criterion #9: The relative feasibility and practicability of the Option, including the ability to fund, engineer, and implement

Option 4 has a high implementation costs and substantial direct effects on the human environment (likely requiring substantial regulatory authorizations), but provides a more flexible approach to addressing the combined goals of species conservation and habitat restoration using practicable technologies.

The geographic area for habitat restoration under Option 4 is the broadest among the Options, maximizing the flexibility in choosing the most cost effective and ecologically effective restoration sites relative to the other Options. Flow operations in the Delta under Option 4 are the least constrained because of the absence of south Delta export facilities and in-Delta barriers. Habitat restoration, therefore, is most feasible as more geographic sites could be made to support the hydrologic conditions conducive to successful habitat restoration for covered species.

The technology for canal and siphon construction for the peripheral aqueduct is proven. A technical uncertainty common to Options 3 and 4 would be the ability to construct a state-of-the-art fish screen on the Sacramento River that will successfully reduce entrainment at the intake of the peripheral aqueduct to negligible levels. Cost practicability of this Option is addressed in Criterion #10, below.

6.2.1.3 Criterion #10: Relative costs (including infrastructure, operations, and management) associated with implementing the Option

Delta Infrastructure Costs

Delta infrastructure costs for Option 4 are expected to be higher than for Options 1 and 2. Option 4 costs relative to Option 3 are uncertain. If the peripheral aqueduct for Option 3 is smaller than for Option 4 and levee strengthening costs for Option 3 are minimized, Option 3 may have lower infrastructure costs than Option 4. Alternatively, if the peripheral aqueduct

were the same size for both Options, infrastructure costs for Option 3 would exceed those for Option 4.

Option 4 infrastructure costs primarily depend on the size of the peripheral aqueduct. As part of the analysis for DRMS Phase II, URS Corporation estimated capital costs for three different peripheral aqueduct capacities: 5,000, 10,000, and 15,000 cfs (DRMS Phase II 2007). The DRMS evaluation assumed the same total volume of water would be diverted under the three capacities, but noted that operational flexibility would significantly diminish as aqueduct capacity decreased. Estimated capital construction costs for the three different aqueduct sizes are shown in Table 6-1. Construction cost estimates exhibit significant economies of scale; a three-fold increase in aqueduct capacity increases estimated capital costs only by a factor of 1.6.[3]

Table 6-1. Summary of DRMS Phase II Peripheral Aqueduct Cost Estimates by Canal Capacity[4]

Canal Capacity	Estimated Cost (2007 Dollars)	Average Cost Per cfs
5,000 cfs	$3.0 Billion	$600,000
10,000 cfs	$4.0 Billion	$400,000
15,000 cfs	$4.8 Billion	$320,000

The DRMS Phase II report provided a more detailed cost breakdown for the 15,000 cfs aqueduct. The estimate is based on previous conceptual level designs and includes contingency, surveys, design, engineering, construction management, and contract administration costs. The estimate does not include financing or environmental mitigation costs; factors that may somewhat reduce the economy of scale of the larger sizes. Route alignment and material quantities for the cost estimate were taken primarily from a cost analysis completed by Washington Group International (WGI) in 2006 (Washington Group International 2006).

The WGI report described two main routes for the peripheral aqueduct. The Route 1 alignment follows the alignment for the originally proposed peripheral aqueduct. The Route 2 alignment shifts a portion of the aqueduct westward to reduce right-of-way costs and avoid residential encroachment. Both the DRMS and WGI cost estimates described herein are based on the Route 2 alignment.

[3] Note that these estimates do not include costs for mitigating construction impacts, which may not exhibit economies of scale to the same degree as construction costs. For example, if the right-of-way footprint for the three aqueduct sizes was roughly the same and siphon construction required roughly the same amount of mitigation, environmental mitigation costs may not vary significantly with aqueduct capacity. Regardless, the general finding of economies of scale is expected to hold due to the likely magnitude of mitigation costs relative to construction costs. For example, supposing unit mitigation cost was the same for all aqueduct sizes, say 15% of the unit construction cost for the 15,000 cfs canal, then a three-fold increase in canal capacity would increase total construction costs (including mitigation) by a factor of 1.7 instead of a factor of 1.6.

[4] Costs in Table 6-1 are drawn from Table 9-2 and Section 15.3.1 of the DRMS Phase II Building Blocks Report. Construction and engineering/management contingencies were added to the intake facility fish screening costs taken from Section 15.3.1 to make them commensurate with the other peripheral aqueduct cost items presented in Section 9 of the DRMS report.

The WGI and DRMS Phase II cost breakdowns for a 15,000 cfs peripheral aqueduct are shown in Table 6-2. DRMS Phase II estimated capital costs of $4.8 billion. WGI estimated capital costs of $3.8 billion. Some of the difference in estimated costs is due to the following differences in design and cost assumptions used in the two evaluations:

- WGI used a higher unit cost for fish screen facilities than DRMS, resulting in approximately a $100-million difference in assumed fish screening cost.

- DRMS assumed higher canal embankment than WGI. The DRMS estimate assumed an embankment elevation of 3 feet above the mean highest high water level. DRMS canal costs are $175 million higher than WGI canal costs.

- DRMS added flow shutoff gates at some of the siphons to prevent large flood events from extending flooding from one island to the next through open siphons. DRMS siphon costs are $344 million higher than WGI siphon costs.

- DRMS included costs for mobilization and demobilization of equipment, materials, and labor, adding $135 million to the estimate.

- Higher DRMS construction costs, including mobilization and demobilization, result in the DRMS construction contingency, engineering, construction management, and administration estimates to exceed the WGI estimates by $459 million.

The likely range in cost for a peripheral aqueduct with a 15,000 cfs canal capacity was developed using the cost estimates from Table 6-2. Taking the lowest estimate for each construction line item in the table created the low end of the range. The high end of the range was similarly created by taking the highest estimate for each line item. Construction contingency and engineering/construction management/administration costs were then added to each estimate. This resulted in a capital cost range of $3.6 to $5.0 billion. Cost ratios calculated from the data in Table 6-1 were then used to scale costs to create cost ranges for 10,000 and 5,000 cfs canals. Results are shown in Table 6-3.

Table 6-2. 15,000 cfs Peripheral Aqueduct Cost Breakdown (millions of 2007 dollars)

Item Description	DRMS Phase II	WGI
Intake, fish screens	282	422
Bridges and culverts	89	56
Pumping plant	230	217
Siphons and controls	1,099	755
Earth Canal	885	710
Control structures for SWP and CVP, maintenance facility, supervisory control and data acquisition systems (i.e., programmable controls)	117	96
Subtotal	2,702	2,256
Mobilization/demobilization (5% of subtotal)	135	0
Subtotal	2,837	2,256
Construction contingencies (30% of subtotal)	851	677

Table 6-3. 15,000 cfs Peripheral Aqueduct Cost Breakdown (millions of 2007 dollars) (continued)

Item Description	DRMS Phase II	WGI
Subtotal	3,688	2,933
Engineering, construction management, and administration (30% and 28% of subtotal, respectively)	1,106	821
Estimated Capital Cost	**4,794**	**3,754**

Table 6-4. Option 4 Delta Infrastructure Capital Cost Range by Peripheral Aqueduct Capacity

Canal Capacity	Low Estimate	High Estimate
5,000 cfs	$2.3 Billion	$3.1 Billion
10,000 cfs	$3.0 Billion	$4.2 Billion
15,000 cfs	$3.6 Billion	$5.0 Billion

Delta Conveyance Disruption Costs

Option 4 avoids the vulnerability of water exports associated with existing through-Delta conveyance, and thus offers significant risk reduction over Option 1. Option 4 is also expected to provide greater risk reduction than Option 2, although its relative advantage would depend on the type and extent of levee improvements undertaken as part of Option 2. Option 4 is expected to provide less risk reduction than Option 3, which has the advantage of conveyance redundancy through the use of dual conveyance facilities.

Compared to Options 1 and 2, Option 4 would be much less vulnerable to events that resulted in failure of the levee system and caused saline water to be drawn into the Delta with significant disruption of CVP and SWP pumping for periods lasting from months to years. DRMS Phase I estimated that, under current Delta conditions, over the next 25 years the likelihood of such an event capable of shutting down CVP and SWP exports for at least ten months was between 50% and 60%, while the likelihood of an event capable of shutting down exports for up to two years was between 30% and 40%. Under the latter scenario, water exports would decrease by 6 to 9 MAF during the repair and recovery period and economic impacts were estimated to range between $10 and $50 billion. The frequency and duration of disruption of water supply and the associated recovery cost under Option 4 would be substantially less than under Options 1 and 2 with the potential to save $10s of billions.

While the risk of export disruption is lower for Option 4 relative to Options 1 and 2, it does not eliminate all risk to Delta water supplies from seismic and flood events. The DRMS Phase II report noted that large events would be expected to result in some damage to canal embankments. However, this damage was expected to be more limited, easier to repair, and would result in much less disruption to water exports. Additionally, the DRMS Phase II report noted that a peripheral aqueduct, if designed with turnouts to the south Delta, could also

facilitate water supply recovery efforts by providing additional fresh water to the south Delta for flushing out brackish floodwater.

Export Water Quality Costs

Of the four Options under consideration, Option 4 is expected to have the lowest costs (i.e., greatest cost savings) related to export water quality. Currently, water exported from the Delta comes from both the Sacramento and San Joaquin Rivers, with flows from the Sacramento River comprising the largest share. The export pumps occasionally reverse the flows of the San Joaquin, Middle, and Old Rivers, resulting in a flushing action that raises total organic carbon and bromide levels in exported water (DRMS Phase II August 2007).[5] Additionally, as water travels through the Delta, its quality is further degraded by tidal influences and returns from agricultural drainages. Option 4 would relocate the diversion point for export water to the Sacramento River near Hood, thereby lowering total organic carbon, bromide, and total dissolved solids levels in export water (DRMS Phase II August 2007). This Option would result in lower water quality treatment and impact costs relative to Options 1 and 2. Option 3's water quality costs might be on par with Option 4's if the dual conveyance facilities of Option 3 were operated to benefit water quality, but Option 4 would be expected to have lower costs if the dual conveyance operations were primarily governed by other considerations.

Water quality improvements under Option 4 would benefit agricultural and urban users of Delta export water. Urban users would benefit from reduced treatment costs and avoided equipment damage and human health costs. South-of-Delta agricultural users may benefit to some extent from slower salt buildup in soils and less need for flushing salts from the root zone.[6] Salt loading is of particular concern in Southern California urban areas. A 1999 study of the problem (USBR 1999) estimated a $95 million annual benefit to urban treatment systems for each 100-mg/L reduction in total dissolved solids of SWP water. Updating to 2007 dollars, the annual benefit would be on the order of $120 million per 100-mg/L reduction in total dissolved solids. Hydrodynamic modeling results for Option 4 indicate that it could lower total dissolved solids in SWP export water by approximately 150 to 200 mg/L.[7] Using the USBR study findings, the present value of avoided salinity damages in Southern California over the next 25 years could, therefore, be on the order of $2.0 to $2.5 billion.[8]

DRMS Phase II noted that construction of a peripheral aqueduct may adversely affect agricultural irrigation water quality in some parts of the Delta, particularly the south Delta, due

[5] DRMS Phase II Report, Section 9.

[6] Improved agricultural export water quality benefits would probably be negligible for south-of-Delta farmland. For impaired lands on the west side of the San Joaquin Valley, the binding constraint is drainage. Without improvements to drainage, improvements in the quality of delivered irrigation water would not be expected to significantly improve productivity on impaired lands. For non-impaired lands, improvements to water quality would provide only negligible production benefits, if any. Over the long-run, better water quality could slow salt buildup and reduce the need for flushing salts from the soil. (Mark Roberson, *pers comm*.).

[7] This estimate is based on converting EC results for export water quality presented in BDCP-ModelingResults_082707.ppt to total dissolved solids using EC to total dissolved solids conversion equations from http://www.iep.ca.gov/suisun/facts/salin/index.html.

[8] The present value calculation of avoided damages uses a real discount rate of 6.0%, per DWR guidance.

to lower flows from the Sacramento River entering the Delta and a return to a more natural pattern in San Joaquin River flows. This reduction in water quality, particularly salinity increases, could adversely impact agricultural productivity in the south Delta, which would offset, to some extent, the benefits associated with improvements in export water quality. DRMS Phase II concluded that additional water quality modeling is needed to define in-Delta water quality impacts and costs of a peripheral aqueduct.

Habitat Restoration Costs

Because it is assumed the overall amount of habitat restoration would be roughly the same across the four Options (though the locations could differ), restoration cost estimates developed with currently available information would not distinguish Option 4 from the other three Options. While it is recognized that unit costs of restoration may vary to some degree according to the range and location of restoration activity, sufficient information on unit restoration cost differentials is not available at this time to distinguish among the four Options. Thus, habitat restoration costs are not treated as a significant distinguishing feature among the four Options.

6.3 FLEXIBILITY/DURABILITY/SUSTAINABILITY CRITERIA

6.3.1.1 Criterion #11: Relative degree to which the Option will be able to withstand the effects of climate change (e.g., sea level rise and changes in runoff), variable hydrology, seismic events, subsidence of Delta islands, and other large-scale changes to the Delta

Option 4 is expected to have the greater ability than Options 1 and 2 to withstand large-scale changes to the Delta that would adversely affect water conveyance. Option 4 would have less ability to withstand catastrophic events than Option 3 because Option 3 includes all of the peripheral aqueduct components as Option 4 plus through-Delta conveyance that provides flexibility to respond to catastrophes. Option 4 is expected to have the greatest ability among the Options to withstand large-scale changes to the Delta that would adversely affect species habitat restoration actions.

Risk to Habitat Restoration Actions

Physical and operational habitat restoration actions under Option 4 are at less risk from seismic or flood events and from the ongoing effects of sea level rise relative to the other Options. Unlike the other Options, restoration actions under Option 4 could be implemented throughout the Delta. Consequently, a levee failure at or near restoration sites would have proportionately smaller adverse effects under Option 4 where restoration sites may be less concentrated than under the other Options where restoration sites would be expected to be distributed within a narrower portion of the Delta. Similarly, because restoration sites may be less concentrated, Option 4 may provide more flexibility than the other Options to adjust flow operations at these dispersed sites in the event of levee failure(s).

Protecting physical habitat restoration against the effects of sea level rise requires restoration sites at higher elevations (sites in the Delta with less subsidence) and with elevation gradients that include an ecotone between tidal and upland habitat (allowing, over decades, the gradual upward elevation shift of all tidal habitats in response to sea level rise). The larger geographic area of habitat restoration opportunities under Option 4 relative to the other Options increases

the number and extent of sites with such elevation characteristics available for habitat restoration in the Delta and, therefore, provides the opportunity for more durability of restored habitat.

Risk to Water Supply Infrastructure

Option 4 would provide the greatest durability of water supply facilities from seismic or flood events and from the ongoing effects of sea level rise of all the Options because all of the conveyance elements (i.e., the peripheral aqueduct) and attendant facilities constructed under Option 4 are expected to be engineered to standards that would withstand probable future seismic and flood events. With the intake on the Sacramento River in the northern Delta, Option 4 water supply is better protected from the effects of salinity intrusion from sea level rise over the long-term than are south and central Delta intake facilities under Options 1 and 2. Option 4 would have less ability to avoid the disruption of export water supply from catastrophic events than Option 3 because Option 3 includes all of the peripheral aqueduct components as Option 4 plus through-Delta conveyance that provides flexibility to respond to catastrophes.

6.3.1.2 Criterion #12: Relative degree to which the Option could improve ecosystem processes that support the long-term needs of each of the covered species and their habitats with minimal future input of resources

Option 4 may be able to sustain improvements in ecosystem processes through time better than Options 1, 2, and 3 for the following reasons:

1. Option 4 would provide the greatest amount of habitat available for management or restoration to improve populations of covered species, thus providing the greatest opportunity for covered species resilience through variable hydrological conditions and climate change effects. This should lead to lower cost to manage through time.

2. Option 4 provides the most opportunity to manage for a more variable Delta hydrology. Although not likely to eliminate recurring costs, this operational flexibility would be expected to reduce the costs associated with controlling harmful invasive species more than the other three Options.

3. Option 4 does not require the continued management, study, and adaptive management associated with the operable barrier installations of Options 2 and 3; thus, Option 4 would require less continued input of resources in this area.

4. Depending on the size of the diversion and effectiveness of the fish screening facility, Option 4 would likely rarely entrain fish. Therefore, it would likely eliminate or greatly reduce costs associated with trucking, hauling, and release of entrained fish, and reduce or eliminate cuts in restricting the timing of export pumping for protection of covered species.

6.3.1.3 Criterion #13: Relative degree to which the Option can be adapted to address the needs of covered fish species over time

Option 4 is expected to provide the greatest flexibility and adaptability among the Options for addressing possible future conservation of the covered fish species for the following reasons:

1. Compared to the other Options, Option 4 provides for the greatest geographic extent and percentage of land area available for habitat restoration should it be necessary to increase the extent of restored habitat for covered species in the future.

2. The flexibility to experiment and adjust Delta hydrology is the least constrained among the Options because the need to maintain a hydrologic barrier to maintain water quality for water supply is not needed. Consequently, Option 4 provides the greatest opportunity for experimenting with flow and water quality conditions (e.g., adjusting operation of the Delta Cross Channel, installing temporary or operable barriers, or augmenting flows to east side tributaries) throughout the Delta to identify flow regimes that optimize ecosystem and covered fish species benefits.

6.3.1.4 Criterion #14: Relative degree of reversibility of the Option once implemented

Option 4 is expected to be less practicable to reverse than Options 1 and 2, but more practicable to reverse than Option 3.

Under Option 4, construction of a peripheral aqueduct with fish screen would entail a substantial investment of capital (see Criterion #10) that would be lost if these facilities were abandoned. Additional costs would be incurred if structures needed to be removed or demolished. Compared to Options 1 and 2, reversing Option 4 would be less likely to be acceptable to the public because the loss of investment costs would be substantially greater than Options 1 and 2. Additionally, the costs and land area subject to disturbance (e.g., noise and road closures) that would be associated with removal of the peripheral aqueduct would be expected to be substantial and, if the aqueduct were not removed, some level of ongoing maintenance costs would be required to maintain public safety (e.g., maintenance of exclosure fencing and patrolling of facility). Reversal of Option 4 could be considered to be more reversible than Option 3 because reversal of Option 3 would also entail loss of investment costs associated with construction of the Option 3 through-Delta conveyance components. However, with dual conveyance under Option 3, reversion to a through-Delta-only conveyance approach, if necessary, would be more rapidly accomplished than Option 4.

6.4 OTHER RESOURCES IMPACTS CRITERIA

6.4.1.1 Criterion #15: Relative degree to which the Option avoids impacts on the distribution and abundance of other native species in the BDCP planning area

The probability for adverse impacts on other native aquatic species within the Delta is expected to be substantially less compared to current conditions and the other Options for the reasons described below:

1. Under Option 4, other native fish and aquatic organisms could be entrained into the peripheral aqueduct at the Sacramento River intake. Placement of state-of-the-art positive barrier fish screens at the intake, however, is expected to minimize entrainment levels and result in minimal impacts on other native aquatic organisms. Consequently, the levels of entrainment of aquatic organisms under Option 4 are expected to be less than levels of entrainment that would be expected from exporting water from the south Delta compared to current conditions and Options 1 through 3.

2. Potential intertidal and aquatic habitat restoration areas are expanded from Options 1 through 3 to include most of the planning area. Because San Joaquin River water would not be exported under Option 4, the proportion of Delta inflow provided by the San Joaquin River would be greater under Option 4 than under the other Options. Because San Joaquin River water quality (e.g., elevated concentrations of salts and selenium) is lower than Sacramento River water quality, there are technical uncertainties associated with restoring aquatic and intertidal habitats in portions of the Delta receiving inflow from the San Joaquin River. This technical uncertainty also applies to Options 2 and 3. The degree of any impacts that could be associated with increasing the proportion of San Joaquin River water entering the Delta, however, would be expected to be somewhat higher under Options 2 and 3, which concentrate San Joaquin River flows along Old River.

3. Construction of the peripheral aqueduct and attendant facilities could result in temporary impacts on water quality associated with sediment discharge or mobilization of channel bed sediments and disturbance to or mortality of aquatic organisms associated with in-channel operation of equipment to construct channel crossings (siphons). These impacts are expected to be temporary and minor, but would be greater than under Options 1 and 2. These impacts would be expected to be somewhat less than under Option 3 because Option 3 includes construction of barriers and a siphon in addition to a peripheral aqueduct and attendant facilities.

The potential for Option 4 impacts on native terrestrial species could result from removal of terrestrial habitats and temporary disturbances (i.e., visual and noise) to wildlife associated with construction of the peripheral aqueduct and attendant facilities. Impacts on wildlife habitats are expected to be substantially greater than under Options 1 and 2 and marginally less than Option 3 for the reasons described below:

1. The probability of impacts on native terrestrial species is expected to be substantially greater under Option 4 than under Options 1 and 2 because no ground-disturbing activities would occur under Option 1 that could affect wildlife and their habitats, and construction of a peripheral aqueduct and attendant facilities would remove a substantially greater amount of habitat and result in greater levels of construction-related disturbance than Option 2. Construction of the peripheral aqueduct and attendant facilities could remove a substantial amount of upland, riparian, wetland, and agricultural land cover types that support habitat for special-status (e.g., greater sandhill crane and Swainson's hawk) and other native wildlife (e.g., waterfowl). For example, up to about 1,200 acres of these habitats were estimated to be removed with construction of the peripheral aqueduct evaluated by CALFED (CALFED 2000). Because the peripheral

aqueduct is a linear facility, habitat would be removed in a relatively narrow band along the east side of the Delta. Consequently, the effects of habitat removal on most terrestrial species are expected to be minimized because habitat would be removed as relatively small patches over a large area and would be restored wherever practicable.

2. Both Options 3 and 4 include construction of a peripheral aqueduct and attendant facilities. However, because Option 3 also includes construction of barriers and a siphon to support its through-Delta conveyance component, impacts of Option 3 on native terrestrial species are expected to be marginally greater to terrestrial species than under Option 4.

3. Construction of the peripheral aqueduct would create a new barrier in some areas to the movement of some species of wildlife that currently use or occupy habitats on both sides of the potential alignment of the peripheral aqueduct. This impact would be common to both Options 4 and 3. The level of this impact would be relatively minor in locations where movement of wildlife is currently constrained by other barriers (e.g., Interstate 5, other roadways, and Delta channels and sloughs).

4. Under Option 4, the west-central Delta could be managed for variable salinity as a tool for species conservation and result in higher salinities during the growing season compared to base conditions. This change in salinity, however, is not expected to affect crops yields sufficiently to reduce their value as foraging habitat for wildlife (Lund et al. 2007). For example, research conducted by Hoffman et al. (1982) indicated that yields of field corn in the Delta were not affected by salinities of less than 3.7 mS/cm.

6.4.1.2 Criterion #16: Relative degree to which the Option avoids impacts on the human environment

The types of adverse impacts as defined under CEQA and NEPA on the human environment that could be associated with Option 4 are described in this section.[9] Potential impacts described here for Option 4 would not necessarily be significant or could be expected to be reduced to a less than significant effect with CEQA/NEPA mitigation.

Option 4 is expected to have greater potential for impacts than Options 1 and 2 and marginally fewer impacts than Option 3 within the following NEPA/CEQA impact categories because the extent of construction-related activities that could impact these categories are greater than Options 1 and 2 and slightly less than Option 3:

- Geology and soils—risk for erosion,

[9] The evaluation of Criterion #16 focuses on the likely range of adverse direct and indirect impacts of the Options in the planning area and not the indirect impacts to water quality and water supply reliability and in the service areas. These issues in the service areas are addressed in Criteria #8 and #11. Options 3 and 4 are expected to be substantially less vulnerable than Options 1 and 2 to future disruption of water supply. Export water quality improvements would be successively greater and attendant impacts on treatment costs, agricultural production, and human health successively reduced under Options 2, 3, and 4 in that order.

- cultural resources—likelihood for encountering cultural resources,
- air quality—PM10 emissions associated with ground disturbance and operation of equipment,
- noise—operation of equipment,
- utilities and public services—likelihood for affecting utility infrastructure, and
- energy usage—fuel and electricity used in construction.

Water Quality/Hydrology

The quality of water, as measured by EC, that would be exported from the SWP/CVP facilities under Option 4 would generally be substantially higher compared to current conditions and to the other Options (see Figure 3-2). Improvements in water quality exported from the Delta relative to current conditions and the other Options, therefore, would be expected to reduce water treatment costs to meet water quality standards and needs for municipal, agricultural, and residential uses in service areas.

Within the Sacramento River Delta (as measured at Emmaton on Sherman Island) and the range of modeled operations most likely to achieve water supply objectives, water quality under Option 4 would generally be higher than Option 1 and compared to current conditions from September through January and generally lower than or similar to Option 1 and current conditions from February through August; generally similar to or higher than Option 2 from May through July and lower than Option 2 from August through April; and generally higher than Option 3 from September through February and lower than or similar Option 3 from March through August (see Figure 3-3). Water quality would be expected to be somewhat higher in the east Delta under Option 4 than under Option 1 because Option 4 would reduce the flow of lower quality San Joaquin River water entering the east Delta. Changes in Sacramento River water quality are expected to have no or minimal impacts on farming practices or production.

Results of hydrodynamic modeling suggest that, within the San Joaquin River Delta (as measured on Old River at State Highway 4) under the range of operations most likely to achieve water supply objectives, water quality under Option 4 would generally be lower than Option 1 and current conditions from December through August and similar to or higher than Option 1 and current conditions from September through November. Option 4 would be similar to Options 2 and 3 from September through June, but higher than Options 2 and 3 during July and August. Changes in water quality in the west-central Delta under Option 4 could potentially affect farming practices or production (see Figure 3-4).

Potential impacts associated with construction-related localized and temporary erosion and runoff of sediments into adjacent Delta waters that could temporarily degrade water quality would be greater than Options 1 and 2 because impacts associated with construction of a peripheral aqueduct would be substantially greater than construction-related impacts of those Options. Impacts of Option 4 would be only marginally less than Option 3, which includes

construction of five barriers and a siphon at Victoria Canal in addition to the peripheral aqueduct.

Aesthetics

The visual impacts of Option 4 would be slightly less than for Option 3 because Option 3 includes construction of through-Delta facilities as well as a peripheral aqueduct, and greater than for Options 1 and 2 because these Option involve construction of fewer facilities near areas of human use.

Hazards/Hazardous Materials

Option 4 would have a slightly lower potential for spills of fuel and lubricants as a result of equipment operation and maintenance during construction of new facilities compared to Option 3 because fewer new facilities would be built. The potential for such spills, however, would be greater than for Options 1 and 2 because more facilities would be built in Option 4 than for either of those Options. Similarly, construction activities under Option 4 would have a slightly lower potential to expose people to hazardous materials and waste uncovered during construction than for Option 3 due to the smaller amount of ground disturbance and a greater potential for such exposure than under Options 1 and 2 due to the larger amount of ground disturbance in Option 4. The peripheral aqueduct in Option 4 could pose a safety hazard to people who attempt to fish or otherwise use the aqueduct; this hazard would be the same as for Option 3 but would not occur in Options 1 and 2.

Transportation/Traffic

Option 4 involves new construction of an aqueduct over 40 miles long, so impacts on transportation and traffic would be substantial. Impact mechanisms would include adding traffic to Delta roadways and potentially requiring modification or rerouting of transportation facilities (e.g., State Highways 4 and 12, local roadways, and railroad lines). Effects would be much greater than under Options 1 or 2. Option 4 impacts on transportation and traffic are expected to similar to Option 3 because construction of the through-Delta facilities under Option 3 is not expected to substantially increase impacts.

Recreation

Option 4 would have greater impacts on recreation than Options 1 and 2 because construction of a peripheral aqueduct could impact access to lands used for recreational activities or reduce the quality of recreational experiences. Option 1 is not expected to affect recreational uses of the Delta and impacts of Option 2 would be less than Option 4 because it does not include construction of a peripheral aqueduct. Option 3 would be expected to have slightly greater impacts on recreation than Option 4 because, in addition to including construction of a peripheral aqueduct, it includes construction of barriers that could adversely affect recreational boating in the Delta.

Agricultural Resources

Because the construction footprint of Option 4 is substantially larger, it is expected to result in a greater loss of agricultural land than Options 1 and 2. Construction of a peripheral aqueduct and attendant facilities could remove a substantial amount of agricultural land from production. For example, removal of 700 to 900 acres of agricultural land was estimated to be necessary for construction of the peripheral aqueduct evaluated by CALFED (CALFED 2000). Because the peripheral aqueduct is a linear facility, it is expected to affect multiple landowners. Consequently, the likely impact of removing land from production would be distributed among a number of individual farmers, thus minimizing the extent of impact on any individual farmers. Impacts on agricultural production under Option 4 relative to Option 1 would be greater if water quality is lowered sufficiently under Option 4 in the central-west Delta.

Impacts of Option 4 are expected to be similar to Option 3 because the likely impacts of constructing the through-Delta component of Option 3 would be minimal and the footprint of the peripheral aqueduct component is expected to be similar to Option 3.

Option 4, however, potentially could have fewer impacts than Option 3 on agriculture in the west-central Delta if water quality under Option 3 is sufficiently lower than Option 4 during July and August to affect crop production.

Environmental Justice. Unlike Options 1 and 2, construction of a peripheral aqueduct and attendant facilities under Option 4 would remove Delta land from agricultural production and, therefore, would be more likely to create disproportionate health or environmental effects on minority or low-income populations through this mechanism. Environmental justice-related impacts of Option 4 would be similar to Option 3 because both Options include construction of a peripheral aqueduct and attendant facilities and impacts associated with the through-Delta component of Option 3 would be minimal.

6.4.1.3 Criterion #17: Relative degree of risk of the Option causing impacts on sensitive species and habitats in areas outside of the BDCP planning area

Adverse or beneficial effects on native species and habitats outside the planning area could result from changes in flow regimes downstream of the Delta in Suisun Bay and Marsh and upstream in the Sacramento River and its major tributaries. The potential for adverse effects downstream of the Delta are indicated by differences in Delta outflow among the Options and the potential for adverse effects in the Sacramento River and its tributaries are indicated by differences in end-of-September reservoir storage volumes, which is a measure of the capacity of reservoirs to provide for cold water releases to sustain water temperatures within ranges favored by native aquatic species.

Based on preliminary analyses, the potential for beneficial effects on species and habitats downstream of the planning area is expected to be greater under Option 4 compared to current conditions and Options 1 and 2 because the modeled average annual outflows under Option 4 (20,996 cfs) is higher than current conditions and Options 1 and 2. The overall range of Delta outflows and likely affect native species and habitats under Option 4 is expected to be similar to Option 3 (20,289 cfs), with Option 4 generally providing for slightly lower outflows in biologically important months of March and April than Option 1, 2, and 3. It is expected,

however, that opportunities could exist to manage operations under Options 4 to improve Delta outflows during sensitive periods to improve downstream conditions for native aquatic species.

Hydrodynamic modeling results suggest that, based on reservoir storage volumes at the end of September, the ability to provide for cold water releases downstream of Shasta, Folsom, and Oroville Reservoirs under Option 4 would be expected to be similar to base conditions and the other Options in most water-year types. During critical water years, Shasta Reservoir storage volume would be less than Options 1 and 2 and similar to base conditions and Option 3; Folsom Reservoir storage volume would be less than base conditions and the other Options; and during dry and critical years, Oroville Reservoir storage volume would be less than base conditions and the other Options. Because maintenance of cold water conditions at Oroville Reservoir is controlled by regulatory requirements, it is likely that Delta operations would be required to adjust (and be different than those modeled for Option 4) to avoid adverse effects on the cold water pool. Maintenance of cold water pool volumes at Shasta and Folsom Reservoirs to protect downstream habitat for spawning and rearing salmonids could be managed under Option 4, in part, by modifications to reservoir releases and downstream exports.